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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : G06F 13/00, H04B 5/00

A1

(11) International Publication Number: WO 90/12366

(43) International Publication Date: 18 October 1990 (18.10.90)

(21) International Application Number: PCT/US90/01736

(22) International Filing Date: 2 April 1990 (02.04.90)

(30) Priority data:
334,083 4 April 1989 (04.04.89) US

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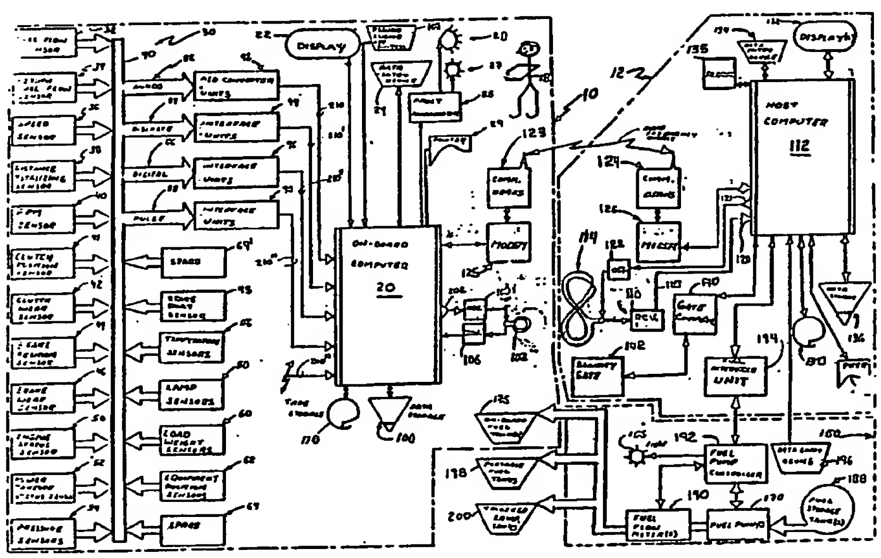
(81) Designated States: AT (European patent), BE (European + patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

**Published**
*With international search report.*

(54) Title: IDENTIFICATION AND PERFORMANCE MONITORING SYSTEM FOR MOBILE EQUIPMENT

(57) Abstract



Sensors (32-64) on mobile machinery (16) detect characteristic parameters of mobile machinery (16). Signals from sensors are processed, and stored in an on-board computing system (20). Upon instruction, the on-board computing system transmits a vehicle identification code, and authorization codes and/or accounting data. The stored parameters are transmitted through a magnetically inductive coupled coil pair (102, 114), whereby current flows through a coil on-board (102) inducing an electromotive force in a fixed coil (114) at a desired base location reducing interference between multiple data transmission systems or outside signal sources. The fixed coil is connected to a host computer system (112) which evaluates data from each machine (16). Upon receipt of acceptable authorization codes and instruction sequences, the host computer system (112) acknowledges receipt and operates or authorizes operation of equipment such as gate openers (140), fuel pumps (192). Keys, coded cards, or user entered identification codes are eliminated.

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# IDENTIFICATION AND PERFORMANCE MONITORING SYSTEM FOR MOBILE EQUIPMENT

## TECHNICAL FIELD OF THE INVENTION

Our invention relates to novel, improved performance monitoring systems for mobile equipment. More specifically, improved apparatus for automatic vehicle identification, for automatic authorization for fuel dispensation, for automatic collection of equipment performance data, and for transfer of such data to a data storage system is disclosed and claimed herein.

## BACKGROUND OF THE INVENTION

Fleets of machinery and equipment such as cars, trucks, trains, buses, and construction machinery are utilized by many business and governmental organizations. Fleet operators need reliable information regarding performance of their equipment on a regular basis. Also, it is increasingly important to monitor human performance factors. Human performance information can be used to establish crew training programs, to modify operations, or to discipline operators as appropriate, to reduce wear and tear on equipment, or to reduce risk of harm to persons or property.

Operators of trucking fleets and construction machinery have been concerned for many years with the reliability of machinery, with the effectiveness of their operating and maintenance personnel, and with the security of their spare parts and fueling operations. A

variety of approaches have been developed in an attempt to provide improved management tools to fleet operators.

Information useful to fleet owners includes engine hours, miles traveled at various speeds, fuel consumption, and other such information which indicates or from which may be deduced the mechanical integrity of the vehicle. Typical measurements include engine revolutions per minute, oil pressure, and engine coolant temperature.

One system for monitoring and recording details of vehicle speed and engine operation utilizes a paper charting method and is well known in the art. It is commonly known as a "tachograph". Analyzing data recorded via this method is labor intensive. Also, the technique is limited to simultaneous recording of only a few parameters.

Also, for fuel dispensing operations, computerized systems have appeared. To date most systems of this type require magnetic cards, punch cards, keypad, or other cumbersome methods for entry of identification codes, instructions, or other data.

Various U.S. patents disclose methods of data acquisition from vehicles, and in particular, show various methods to provide a vehicle fueling system with identification and recording systems:

In particular, U.S. Patent No. 4,630,292 issued to Juricich et al. on 16 December 1986 provides fuel measurements for the purpose of obtaining fuel tax exemption and rebates for non-highway use, based on measurement of hours of operation on-highway and off-highway. The method relies on independent measurement of an overall average of gallons used per hour, and then converts hours of use to gallons of use

in each category. Since total fuel use in each category of operation is not discretely determined, data produced by this method may be unacceptable to taxing authorities.

U.S. Patent No. 4,263,945 issued to Van Ness on 28 April 1981 has a system transferring a vehicle's identification data between the vehicle and dispensing pump. However, Van Ness' communication method utilizes low power radio signals which cannot discriminate between signals from multiple vehicles in close proximity to the dispensing pump, such as occurs when a pump bay is configured to serve multiple lanes of traffic. Noise or interference from radio broadcasts may also cause difficulties in this Van Ness system. This is a severe disadvantage in large fleet operations. Also, although the '945 patent measures hours and miles traveled, the method does not acquire sufficient operational information to adequately monitor human performance factors. Van Ness also does not provide for additional fueling activities such as filling portable containers or fuel tanks on trailered vehicles. Therefore, his method does not provide a way to record sufficient information to obtain all available fuel tax rebates.

Fuel consumption measurements are important in vehicle performance monitoring systems. Gasoline fueled engines normally have a single fuel supply line, and all fuel flowing through the fuel supply line is consumed by the engine. Thus, measurement of fuel flow through the line provides a reliable measurement of fuel consumed. In general, however, diesel engines utilize a "two pipe" or "return flow" type of fuel supply system, where a circulatory fuel loop supplies fuel to the injector fuel

supply line, and only a portion of fuel circulating is injected into the engine and combusted. Initial fuel consumption measurement systems metered the flow in both the fuel supply and return loops and determined the difference between the flow in the two lines. However, air can become entrained in the fuel flow if the suction seals of the fuel pump leak. Cavitation can also occur where fuel pressure is reduced as fuel leaves the engine and enters the return line to the fuel tank. Thus, due to the presence of gases in the return flow line, and to differing density and viscosity of the heated fuel in the return line when compared to the cold fuel in the supply line, simple differential fuel flow readings were not reliable. Therefore, various techniques have been developed to minimize errors in measuring fuel consumption in "return flow" fuel supply systems.

One technique, described in U.S. Patent No. 4,450,820 issued to Haynes on 29 May 1984, employs a recirculation tank and is designed for diesel engine service. Haynes' invention utilizes an atmospheric vent to discharge accumulated gases, and the device must be fed by gravity or pump. A float valve allows fuel to bypass the fuel measurement meter if fuel flow to the engine is blocked by foreign matter or by failure of the meter. This system depends upon proper functioning of relatively complex float and mechanical linkages to relieve pressure, and it would at best be difficult to retrofit existing vehicles with the Haynes system.

U.S. Patent No. 3,672,394 issued to Erwin on 27 June 1972 discloses a system with a degassing tank using baffles to enhance the separation of bubbles from fuel. Erwin's baffles are oriented either in a vertical or near vertical configuration in the degassing tank, or

in a slanted arrangement where a portion of the baffled space extends below the liquid level; both approaches result in less than optimum separation of bubbles from fuel. Thus, advantages inherent in a degasifier are partially defeated.

U.S. Patent No. 3,817,273 also issued to Erwin, on 18 June 1974, discloses a float equipped system for metering fuel into a combination fuel and fuel return line. However, the Erwin '273 device does not disclose a method to minimize or to prevent volatile organic hydrocarbon constituents which are separated from returning fuel from subsequently escaping to the atmosphere.

## SUMMARY OF THE INVENTION

The present invention is directed to an improved apparatus and methods for identification and performance monitoring of mobile machinery. As used herein, the terms "mobile machinery," "vehicle," and "equipment" are used interchangeably, and are intended to include motor vehicles, transportation equipment, and construction machinery, or the like.

The identification and performance monitoring system of the present invention has two major sub-systems, first a mobile sub-system which includes an on-board computer, an output oscillator and a coil, and second, a fixed base sub-system which includes an input coil and a receiver operatively connected to a central computer system. Optionally, a third sub-system for data acquisition or data exchange at remote locations may be provided; such a system is essentially a

duplicate of a fixed base sub-system, although it would commonly utilize less computing capability.

The mobile apparatus sub-system generally has: (i) sensors which acquire data from a plurality of detectable characteristic parameters associated with the mobile machinery, (ii) interface units which convert all sensor signals to filtered and shaped digital electronic signals for receipt by a computer, (iii) an on-board information management system (IMS) computer for processing and storing acquired sensor signal data, (iv) optional display and interface devices for the machinery operator, and (v) an output device for transmitting stored data, with associated input equipment optional.

The fixed base apparatus sub-system has: (i) an input device for receiving identification codes, and performance data from IMS on-board computers (output equipment optional), and (ii) a host computer which receives data records from one or more mobile vehicles and which evaluates incoming authorization codes and instruction sequences, and which, upon receipt of acceptable authorization codes, outputs a signal to operate or authorize operation of equipment such as security gates, fuel pumps or the like.

The optional remote location sub-system has an input coil and receiver for receiving identification codes, authorization codes and performance data from one or more mobile vehicles. Output equipment at a remote location sub-system is optional. In response data received, the fixed base sub-system provides a signal which initiates the operation or which authorizes operation of equipment such as a security gate. When the remote location sub-system is equipped with an output capability, and correspondingly the mobile

vehicle apparatus is equipped with input capability, the remote location sub-system may be configured to trigger vehicle data and status reporting. This is a function which is particularly useful to indicate the beginning and end of off-highway operations, as may be desirable for tax records.

In the preferred form, the input/output capability referred to above includes two coils, one located at the fixed base and one in the mobile vehicle, which are configured and located so that data communication is achieved through an inductively coupled coil pair. Electric current flowing through an output coil sets up a magnetic field that induces an electromotive force in an associated input coil. This mutual inductance technique reduces or eliminates interference between multiple data transmission systems operating in close proximity. Such close proximity operation is common on vehicles which are positioned in adjacent fuel loading bays. The technique of the present invention reduces or eliminates interference from similarly equipped vehicles or from outside signal sources.

The present invention also provides means for reliable measurement of fuel consumption. This function is critical to data acceptance by governmental authorities which examine claimed exceptions for non-taxable fuel use. The present invention is also superior to previous apparatus known to us for removing gas bubbles from diesel engine fuel loops. This is because it provides a totally enclosed system for returning to a vehicle fuel tank all vapors removed from a vehicle's hot fuel return loop. This novel improvement also allows a fuel debubbler to be located

at any desired elevation, rather than restricting a fuel debubbler installation to a gravity fuel flow configuration.

It can be seen then that the present invention provides improved equipment identification, performance monitoring data, and improved data off-loading reliability, thus allowing cost effective operational, maintenance, and personnel risk management programs.

## OBJECTS, FEATURES, AND ADVANTAGES OF THE INVENTION

In order to overcome problems inherent in known methods and apparatus, it is an object of the present invention to reliably acquire, process, store, and transfer digitally encoded identification and performance data from mobile machinery.

It is a further object of the present invention to automatically off load vehicle data.

It is another object of the present invention to off load data without interference from adjacent equipment.

In addition, an object of the present invention is to record relevant machine data and human performance data and information for later review and disciplinary action as appropriate.

Another object of this invention is to provide an improved equipment performance monitoring system with a capability for the monitoring and recording of the vehicle mileage and hours of use.

Yet another object of this invention is to provide an improved system for preventing the dispensing of fuel under unsafe conditions, for example, when a vehicle's engine is running.

Yet another object of this invention is to prevent dispensing of the incorrect type of fuel to a vehicle by automatically preventing pumps for fuels incompatible with vehicle requirements from being placed into an operative condition.

It is a further object of the present invention to control the amount of fuel dispensed to a particular vehicle.

A still further object of this invention is to provide a system for totalizing and recording the volume of fuel dispensed during each machine or portable container fueling operation.

A still further object of this invention is to provide a system for sending a digital output message containing preselected information to an external data storage system at the completion of a fueling operation.

A still further object of this invention is to provide a reliable method for measuring fuel consumption in engines which utilize a fuel return line, such as diesel engines.

It is a feature of this invention that a fuel dispensing system is activated only to service properly authorized mobile equipment.

As an additional feature, this invention can be configured to provide a system which will limit access to a fueling site or other security area to authorized vehicles only.

Another feature of this invention is the capability to control fueling equipment to select the type of fuel which may be dispensed to a given vehicle.

Another feature of this invention is the ability to select the quantity of fuel which may be dispensed to a given vehicle, such as a limit of the

maximum capacity of the vehicle fuel tank, so as to prevent fuel loss.

Another feature of this invention is the ability to enable the dispensing of fuel to portable containers, accessory fuel tanks, and fuel tanks on trailered vehicles without the necessity of special access and accounting codes, by using the vehicle identification and authorization to provide required fuel pump access.

It is an advantage of the present invention that the problems inherent in use of data entry devices known to us, such as magnetic cards, punch cards, optical character readers, and the like, are avoided.

It is a distinct advantage of the present invention that data transfer is simple, more reliable and less prone to interference than previous methods known to us.

It is a further advantage of this invention that separate accounting is achieved between fuel used for taxable applications and fuel used in non-taxable applications.

Additional objects, advantages and novel features of the invention will become apparent to the reader from the foregoing and from the ensuing detailed description in conjunction with the accompanying drawing and appended claims which follow.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more clearly understood by reference to the accompanying drawings thereof, wherein:

FIG. 1 is a schematic of a data acquisition and storage and instrumentality enabling and operating system for mobile equipment which: embodies the principles of the present invention and includes an IMS computer on-board the vehicle, a central host computer which receives and processes incoming data, and various sensing devices and peripherial equipment devices for acquiring data and storing data;

FIG. 2 is a schematic of a fueling yard with input and output communication devices constructed and positioned according to the principles of the present invention;

FIG. 3 is a schematic which illustrates one embodiment of an output oscillator as utilized in the present invention.

FIG. 4 is a schematic of a second embodiment of an output oscillator which may be utilized in the present invention.

FIG. 5 is a schematic of a receiver utilized in the present invention;

FIG. 6 is a schematic (IMS) computer;

FIG. 7 is a schematic of a second (IMS) computer which may be employed in systems designed in accord with the principles of the present invention;

FIG. 8 is a schematic of a remote location identification or data transfer device which may be employed in the system of FIG. 1;

FIG. 9 is a schematic illustrating the organization of a vehicle identification and performance monitoring data set for the system of FIG. 1;

FIG. 10 is a schematic of a prior art fuel system with dual flow lines and meter devices;

FIG. 11 is a schematic of a dual line fuel system with a debubbling device and a single fuel flow metering device;

FIG. 12 is a schematic of a duel line fuel system with a debubbling device and fuel measurement in both lines according to the principles of the present invention;

FIG. 13 is a schematic of one type of a venturi device which may be utilized to provide pressure reduction in diesel fuel return flow loops; and

FIG. 14 is a schematic of a second embodiment of a venturi type device which may be utilized to provide pressure reduction on diesel fuel return flow loops, while including a flow measuring capability.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a novel and improved apparatus and method to identify vehicles and to monitor their performance. The apparatus and method utilized by our invention provides improved reliability in fuel use measurements, and provides improved reliability in the automatic transfer of data to host computer systems from performance monitoring equipment on mobile equipment.

Reference is first made to FIG. 1, which illustrates schematically a vehicle identification and performance monitoring system of the present invention. A simple vehicle identification and performance monitoring system is generally comprised of two functional sub-systems, namely (i) mobile apparatus 10 which provides a vehicle or mobile equipment identification signal and which may also acquire, store, process, and output data, and (ii) fixed base apparatus 12 which receives data which is output from mobile apparatus 10, and which also may activate and deactivate various devices (e.g., fuel pumps) as authorized and instructed, as well as store and process data from mobile machinery or equipment 16 to generate desired reports.

Mobile machinery 16, such as a truck, bus, bulldozer, or other equipment having a power source such as an engine 17 and normally (but not necessarily) an operator 18, has mounted thereon mobile apparatus 10. The heart of the mobile apparatus 10 is an information management system (IMS) on-board computer 20.

In a basic embodiment, the IMS on-board computer 20 may be provided as a "black box" without any

devices for feedback to the machinery operator 18. In enhanced embodiments, the IMS on-board computer 20 may be configured to provide equipment for both input from and feedback to equipment operator 18. Such input and feedback equipment may include an on-board video display 22, a data entry device 24 such as a keyboard or barcode reader, a fault annunciator 26 with a plurality of indicating devices such as lights 27, 27', etc., or audible alarms 28, 28', etc. Indicating devices such as light 27, alarm 28, or other suitable fault annunciator means 26 may be configured to bring malfunctions to the attention of the operator 18, or to provide warnings to operator 18 in the event of unsafe operations, such as excessive speed. In many applications, a printer 29 can be effectively utilized to print desired reports such as malfunction records, customer invoices, or bills of lading. One desirable function is to print out log book data required by regulatory authorities, particularly as may be needed to meet U.S. Department of Transportation requirements.

Power supply for the on-board computer 20 is normally provided from the DC power supply (not shown) of mobile machinery 16. In addition, to protect internal memory of on-board computer 20, a small "keep safe" battery (not shown) is normally supplied to maintain electrical power necessary for operation of digital data storage devices. This "keep safe" battery thus preserves stored data and instructions for short periods of time in the event of failure of the main electrical power supply of machinery 16.

A plurality of sensors 30 are operatively positioned to sense detectable characteristics from a variety of sources on the mobile machinery, vehicle, or

equipment 16. Sensors 30 may include any one or more of the following: fuel flow sensor 32; a second or return fuel flow sensor 34 (use of dual fuel flow sensors is discussed below); a vehicle speed sensor 36; a distance totalizing sensor (odometer) 38; and engine revolution per minute sensor (tachometer) 40; a clutch pedal position or clutch pedal depression counting sensor 41; clutch wear sensor 42; a brake pedal position or depression counting sensor 44; a brake wear sensor 46; an engine status sensor 50 (used to signal to the IMS on-board computer 20 whether the engine is on or off); a power takeoff (PTO) status sensor 52 (used to determine whether or not a power takeoff apparatus is in use); miscellaneous pressure sensors 54, 54', 54'', etc. as necessary to determine pressure at various points such as oil pressure, tire pressure, transmission fluid pressure; miscellaneous temperature sensors 56, 56', 56'', etc. as necessary to determine various temperatures such as engine oil temperature, engine coolant temperature, transmission fluid temperature, ambient air temperature, engine inlet air temperature, etc.; miscellaneous lamp sensors 58, 58', 58'', etc. as necessary to determine the status of various lamps, such as headlamps, brake lamps, marker lights, parking lights, or the like so that lamp switch position and actual lamp illumination can be determined and recorded; a load weight sensor 60 useful for determining the load weight on a machinery 16, equipment position sensors 62, 62', 62'', etc. as necessary to determine the position of various equipment components (not shown) such as the extension of an excavation implement or the extension of a log-loading boom, etc.; a brake fault sensor, in particular to sense a dragging brake and/or over-center

operation of an air brake actuating cam; and spare sensor locations 64 for subsequent addition to the on-board monitoring system 10 as desired in a particular service.

Sensors 30 for each type of sensing requirement may be selected from a wide variety of available choices which are well known in the instrumentation and control industry. Sensors 30 are available in a variety of shapes, sizes, materials, and thicknesses, and they may be specifically selected to suit the requirements of a particular application. For instance the brake pedal sensor 44 could be a simple mechanical force actuated device which completes or interrupts an electrical loop, or it could be selected from other types of sensors such as inductive and capacitive proximity sensors which can sense the presence of either metallic or non-metallic objects without direct object to object contact. Alternatively, a brake pedal position sensor 44 can be configured to utilize a linear position indicating transducer which indicates displacement of a brake pedal over a continuous range of positions, i.e., from no displacement or braking force applied to displacement for full braking force. From such a linear position indicating device for brake pedal sensor 44, the IMS on-board computer 20 may be programmed to evaluate the amount of brake pedal travel remaining for use, and to activate fault annunciator means 26 when the remaining pedal travel distance for further braking force application is below a predetermined minimum specification. Also, sensor devices 46 for sensing brake wear may be configured to provide a continuous measurement of brake wear, or may be simply a conductive

end-switch type signal, such as an embedded contact in the brake shoe, or a contact mounted on a brake actuator mechanism to generate a warning signal when a brake shoe is worn out.

The selection of sensors 30 may result in a variety of types of signals from such sensors. Sensors 30 may generate analog signals 82, 82', 82'', etc.; sensors may generate discrete signals i.e. on-off type, signals 84, 84', etc.; sensors may generate digital signals 86, 86', etc., or sensors may generate pulse signals 88, 88', etc. From sensors 30, signal transport means 90, 90', etc., may be provided as appropriate, such as wires for electrical signal transport, for fiber optic cable for optical signal transport, or other conduits as necessary for other mediums such as sound or pressure signals. Analog signal sources 82 must be converted to electrical digital signals by analog/digital converter 92, 92', etc. Discrete signal sources 84, 84', etc., must be converted to electrical digital signals by an appropriate interface unit 94, 94', etc., which may vary according to the type of discrete signal 84 being generated. Interface unit 98, 98', etc. prepares pulse signal sources 88, 88', etc. for transmission to the IMS on-board computer 20. Generally, signal sources 82, 84, 86, and 88 require further processing by corresponding interface units 92, 94, 96, and 98, each of which converts signals to electrical digital signals as required. A noise filter and pulse shaper are also included in interface units where required, and such provision may be accomplished by a variety of well known methods which will not be discussed further herein.

One embodiment of the IMS on-board computer 20 is comprised of a transmit only configuration, wherein the on-board computer 20 continuously accumulates data, and, when a transmit instruction is triggered, the computer 20 repeatedly offloads data via output oscillator 100 and coil 102. Normally, the IMS on-board computer 20 will be configured to trigger data transmission when engine status sensor 50 indicates that the engine 17 has been turned off. Alternately, a pseudo engine off switch 104 can be provided. The number of repetitions of the data transmission can be programmed into computer 20 as desired.

In an enhanced embodiment, the on-board computer 20 can be provided in a configuration that can both transmit and receive, where the on-board computer 20 is able to both offload data upon command and is able to receive data and/or programming instructions from the fixed base apparatus 12, or from other similar devices. In cases where input to on-board computer 20 is desired, computer 20 will be operatively connected with a mobile receiver 106 in addition to previously provided output oscillator 100 and coil 102. Thus, when input to on-board computer 20 is desired, the coil 102 also functions as an input coil to detect incoming magnetic signals.

Another enhancement to on-board computer 20 which is useful in many applications is a data storage device 108 such as a large capacity hard disk or additional memory boards. Other types of data storage devices may also be utilized, such as a tape data storage unit 110.

For receiving, storing, processing and outputting data and generating reports from one or more

on-board computers 20 in a fleet of trucks or other mobile machinery 16, fixed base apparatus 12 is provided. The host or central computer 112 is the central element in fixed base apparatus 12.

Data transmitted from on-board computer 20 via output oscillator 100 and via coil 102 is detected at fixed base coil 114. Signals detected by fixed base coil 114 are conditioned, filtered and amplified by receiver 116 to provide a signal suitable for receipt by host computer 112. Signals from receiver 116 are conducted by cable 118 to a serial port 120 of host computer 112.

When host computer 112 is utilized in an output mode, the data output from the host computer 112 is sent from a serial port 121 of computer 112 to fixed base output oscillator 122 to generate a suitable magnetic signal in coil 114. In the output configuration, coil 114 functions as a magnetic output device, in a manner similar to that described more completely hereinafter for coil 102.

Communication may alternately be established between on-board computer 20 and host computer 112 by utilizing on-board communication means 123 and similar fixed based communication means 124. Communication means 123 and communication means 124 may be radio transmitters, cellular telephones, satellite communication links, or other long distance radio frequency communication or telecommunication methods. Where communication means 123 and 124 are employed, on-board modem means 125 and fixed base modem means 126 may be utilized to modulate signals to provide for transmission and reception of digitally encoded information.

The host computer 112 may also be provided with one or more video display units 132 and one or more data entry devices 134 such as a keyboard. An alarm 135 is frequently desirable to alert managers to unauthorized operations which are attempted. Another enhancement to host computer 112 which is useful in many applications is a data storage device 136 which may take the form of a large capacity hard disk or additional memory boards for attachment to the host computer 112. Also, a tape data storage unit 138 can be utilized. For generating hard copy reports, a printer 139 is provided.

When desired, an identification feature may be provided by data transmitted to or from either the on-board computer 20 or the host computer 112. Such identification data, or corresponding acknowledgement data from the initial receiving computer, may be utilized to provide authorization codes to security devices such as a yard security gate controller 140. Thus, utilizing the present invention a machinery operator 18 can position his equipment near a yard security gate 142, and the IMS on-board computer 20 will provide identification and authorization data to IMS host computer 112. This would be accomplished by utilizing a separate coil 124' and receiver 127' (not shown) as necessary to detect signals from on-board computer 20. Such detected signals would be input to host computer 112, which, through suitable computer program means, will in turn automatically trigger the yard security gate controller 140, thus opening the gate 142. This is a unique advantage for those locations where it is undesirable for the operator 18 to leave his operating position, such as during inclement weather or in extremely cold climates.

Referring now to FIG. 2, the present invention is illustrated in the context of a fuel dispensing station 150. Fuel dispensing is utilized as focal point for the present vehicle identification and performance data acquisition system. This is because fueling is the most regular service that any vehicle receives. However, although data transfer is preferably conducted at a fuel dispensing station 150, the location of yard security gate 142 may be used as an alternative location for identification and/or for data transfer. In FIG. 2, a tractor 152 with trailer 154 is shown in suitable location for off-loading data while in a fueling bay 160. Such suitable location may be ascertained by an equipment operator 18 by any convenient means, including use of visual striping 162 on the surface of fueling bay 160, by use of a monument 166, or by any suitable means whereby an operator 18 may position the coil 102 on tractor 152 in an operative location with respect to fixed base coil 114 located in fueling bay 160.

It is a feature of the present invention that by suitable design of coils 102 and 114, and by controlling the location of coil 102 relative to location of fixed base coil 114 located in fueling bay 160, that a magnetic inductive coupling effect can be achieved between coil 102 and coil 114. Thus, data transmission is through an inductively coupled coil pair, i.e., between coil 102 and coil 114, whereby a current flows through a coil 102 on-board the mobile machinery, setting up a magnetic field that induces an electromotive force in a fixed coil 114 located at a desired base location. The process is reversed when transmission is from the fixed base coil 114. Data

transmission through the mutual magnetic inductance technique reduces or eliminates interference between multiple data transmission systems or from outside signal sources. This magnetic inductively coupled loop enables good communications between properly positioned devices so that near field communication is achieved. while avoiding "cross talk" or other interference which is inherent in prior devices which rely on radio communications. For example, due to the magnetic inductively coupled effect relied upon for sending and receiving data, the present invention can be utilized with multiple fixed base coils 114, 114', etc., and multiple tractors 152, 152', 152'' etc., each equipped with a coil 102, with tractors in fueling bays 160 on opposing sides of a fueling island 168.

The coils 102 and 114 are generally operated at a frequency between 50 and 500 kilohertz, preferably between 50 and 250 kHz and normally at 100 kHz, at low power. The desired operative axial distance between coils 102 and 114 is 30 inches or less, however operation is feasible at distances up to approximately 10 feet. Coil 102 is normally configured as an elliptical or circular coil, while the fixed base coil 114 is normally generally configured in a figure eight ("8") shape. While the figure eight may be circular with a diameter of each loop the "8" of approximately four (4) to five (5) feet, in a preferred embodiment, the loops are approximately rectangular in shape with similar each side three (3) to five 5) feet in length. The coil 114 is embedded within the surface of a roadway or fueling bay as desired. The figure eight shape of the coil 114 is helpful in eliminating far field signals which may be picked up by the

coil 114. In a typical application, the coil 102 may be configured as a part of a tuned circuit power oscillator or amplifier with an output power of about 500 milliwatts, with a coil 102 inductance in the range of 50 microhenrys. When in the receiving mode, a fixed base coil 114 having an inductance of 200 microhenrys will produce an acceptable signal voltage of approximately 10 millivolts when an alternating magnetic flux of $1.3 \times 10^{-13}$ rms gauss is applied from the mobile vehicle coil 102.

A simple coil of several turns would be the simplest configuration of the fixed base pick-up coil 114, because it is readily analyzable and predictable. However, such a coil configuration is also used in certain types of radio broadcast receiving applications. Thus, such a configuration would be potentially susceptible to interfering signals from broadcast and noise sources, such as low frequency navigation broadcast signals, marine low frequency radio communications, lightening, gas discharge lamps, and even sixty (60) cycle per second magnetic fields from power lines.

According to antenna theory, all conductors carrying alternating electric current, whether a closed circuit (i.e., a loop) or open circuit (i.e., an insulated antenna), radiate electromagnetic energy in the form of electric and magnetic fields. Such energy fields may be grouped in two categories, the near-field and the far-field. Near-field is defined as distances from the antenna that are small compared to wavelength.

The characteristic of energy patterns in the near-field is that with antennas the dominant field is the electric field, and with loops the dominant field is

the magnetic field. Radio antenna devices tend to be omnidirectional, however a loop acting as an antenna for radio waves is least sensitive to signals coming from directions along its primary axis, i.e., those directions perpendicular to the plane of the coil. The magnetic loop of the instant invention is highly directional, providing the capability to more completely isolate physically adjacent pairs of transmitters and receivers.

The instant invention relies on near-field phenomenon. The coil is situated to receive magnetic signals from sources along the primary axis. Thus, radio frequency interference from sources generally along a primary axis, such as overhead lighting, will result in minimal interference. However, since the instant invention utilizes magnetic inductive coupling, rather than relying upon radio reception techniques, the potentially serious problems associated with radio frequency interference are substantially avoided.

A further feature of the instant invention unavailable in prior systems known to us, is that by relying on the directivity and well defined zone sensitivity of a loop antenna structure operating in the near-field mode, a receiving antenna system consisting of two opposed loops may be constructed such that one loop communicates with the vehicle transmitting loop, and the other is beyond the zone of sensitivity. Thus, communication with the vehicle is established, while interference arriving from distances a few loop diameters away impinges on both loops equally and the induced signals cancel, thus the loop antenna system effectively rejects stray radiation from every direction.

The instant invention, in the preferred embodiment, uses low frequencies, i.e., frequencies of long wavelength. In theory, it will work at all frequencies. However, because of the geometry of the application, frequencies above approximately 30 megahertz (10 meters wavelength) may not utilize near-field phenomenon and would clearly be classified as radio means.

In practice use of the instant invention, utilizing magnetic induction in a near-field, at frequencies below 550 kilohertz are less likely to cause interference with, or to be interfered with, by established radio communication services both because the low frequency spectrum is not as filled with users and because the radiation efficiency (far-field) of electrically tiny antennas is so low the signal strength at distance will be minimal.

A "figure-eight" configuration of input device 114, consisting of two loops 114a and 114b which are phased in opposition will tend to reject interfering signals from any direction while preserving the near-field sensitivity of each loop coil 114a or 114b individually. One loop, either 114a or 114b, will be active and will be inductively coupled to the output coil 102. The other loop will be beyond the zone of the sensitivity and will not be inductively coupled to output coil 102. The only effect of the inactive loop on the desired signal from the output coil 102 will be to present an inductance in series with the signal voltage generated in the active loop. That inductance becomes part of the band-pass filter system of the receiver 116. There is a small zone of insensitivity directly above the common section 114c of the loops 114a

and 114b. However, this zone of insensitivity is small in size and can be suitably located so as to minimize loss of signal strength.

Other combinations are available for design of loops 114a and 114b, wherein the areas and turns are balanced to further cancel far field signals. In particular, a three-loop configuration may be useful forming particularly sensitive side loops, at the expense of the sensitivity of the center loop.

It is a feature of the instant invention which utilizes magnetic inductive coupling that the zone of sensitivity is sharply defined. Communication is limited to the region bounded by the periphery of the structure of fixed coil 114. By properly locating the coil 114 in relation to the position of fuel pumps 170, 170', etc., geometry of the fuel dispensing station 150 is controlled so that the inlet 174 to on-board fuel tanks 176 will be located within reach of hose 180 of fuel pump 170. Thus, in a preferred configuration, when machinery or equipment 16 is stopped for refueling, the inlet 174 to on-board fuel tank 176 is within reach of fuel hose 180 of fuel pump 170; in such cases, the coil 102 associated with mobile monitoring apparatus 10 should be located in a suitable position which is within the zone of sensitivity of coil 114.

The vehicle identification and performance monitoring system of the present invention is normally configured to automatically identify the machinery 16, to identify the type of fuel required, the size of on-board fuel tank 176 (to limit maximum amount of fuel dispensed), to unlock or energize the proper fuel pump 170, and to selectively identify appropriate billing codes and other accounting information.

Whenever an instrumented machine or vehicle such as tractor 152 stops along side fuel dispensing pumps 170, 170', etc., an indicator such as an indicator light 186 can be energized to signal to the driver or operator 18 the appropriate pump 170 for fueling his tractor 152.

As fuel is removed from fuel storage tanks 188, 188', etc., and pumped via pumps 170, 170', etc., the quantity of fuel transferred is monitored by fuel flow meters 190, 190', etc. In some systems and particularly in a complex system, the activities of a plurality of fuel pumps 170 and metering devices 190 may be monitored and controlled by a fuel pump controller 192 located between the host computer 112 and pumps 170. Depending upon the configuration of fuel pumps 170, meters 190, and fuel pump controller 192, an additional fuel interface unit 194 may be required to provide signal translation, conditioning, and buffering prior to input to host computer 112.

If required, a separate data entry device 196 such as a keypad, keyboard, card, barcode, reader, or the like, can be used to identify the fuel requirements for portable containers 198, as identified in FIG. 1. The same technique can be utilized for trailer mounted equipment fuel tanks 200 or other devices where it is appropriate to separately authorize and record the fuel used. Separate fuel use identification is particularly important for those applications where the fuels are exempt from highway taxes. The present invention is specifically configured to achieve sufficient recordkeeping to enable users to obtain appropriate tax rebates.

FIG. 3 is a block diagram which illustrates one embodiment of output oscillator 100 and coil 102.

The coil 102 is utilized for both output through oscillator 100 and for input through receiver 106, and is simultaneously connected to both. The two electronic circuits oscillator 100 and receiver 106 are electronically separated from each other by design, due to the impedance of each when the other is operating, rather than by use of more commonly employed switching means.

Still referring to FIG. 3, the circuit diagram of the output oscillator 100 is illustrated. Coil 102 is tapped at a turns ration of 11 to 2, 102a being the 11 turn transmit portion, 102b being the 2 turn feedback portion. The output oscillator 100 circuit will be recognized as either a modified Hartley design or a Tuned Output Reverse Feedback design.

Coil portion 102a is resonant with capacitors C1 and optional capacitor C1'. C1' is utilized when necessary for tuning purposes to compensate for manufacturing tolerances in coil 112 and capacitor C1. Coil portion 102b is inductively coupled to portion 102a and introduces a portion of the electrical energy circulating in the resonant circuit to the control element (base) of the oscillating transistor Q1. A biasing current is supplied to Q1 through resistor R1 as necessary for operation; capacitor C2 bypasses the feedback current around the impedance of resistor R1. Capacitor C3 provides a low impedance path to ground for the operating frequency. This effectively provides an alternating current ground for coil 112a.

Transistor Q2 is the keying transistor for output oscillator 100. When transistor Q2 is turned on because of an output current from the output port 202 of

computer 10, transistor Q2 diverts the bias current away from the base of transistor Q1, removing the operating bias and causing oscillation to cease. Thus, transistor Q2 is a keying means by which the output oscillator 100 is turned on and off in response to an output digital signal from computer 10.

It should also be pointed out that this invention is not dependent on the use of junction transistors as shown in this FIG. 3, but will operate equally well using field effect transistors or even vacuum tubes.

Resistor R2 is a current limiting resistor, which may be in come circumstances be unnecessary. Because there is some oscillating voltage at the base of transistor Q1, the transistor Q2 also acts as a buffer to block high frequency voltage from entering the output port 202 of computer 10.

Since the operative phenomena utilized for communication in this invention is electromagnetism, the current circulating in the coil 102 is a key parameter. However, a variety of oscillators using resonant coils may be used in the present invention without diminishing its performance. A tuned amplifier excited by a signal from an independent oscillator or derived from the computer 10 clock system would be equally satisfactory. The designer's choice is thus a trade between simple self-tuning circuits (oscillator) with potential frequency instability, or a tuneable circuit and frequency stability. Temperature stability of components over the expected operating range, the cost of tuneable elements at low frequencies, and packaging considerations are the dominant points of consideration. Primarily due to cost considerations, the preferred

embodiment illustrated utilizes a simple self-tuning circuit for oscillator 100.

FIG. 4 is an alternate embodiment for an output oscillator, here designated as oscillator 100', utilizing frequency shift keying (FSK) means. Except for the frequency shifting elements (discussed below), the basic oscillating circuit is virtually identical to the embodiment first illustrated in FIG. 3. Transistor Q30 connects and disconnects capacitor C40 in parallel with capacitor C10, with the capacitance of C40 being small relative to C20 (i.e., in order of approximately 30% of C20). This causes the output frequency to shift by a factor of the square root of (C40+C20/C40.

Hold over oneshot 204 is a monostable multivibrator which resets itself on every input pulse. The hold over oneshot 204 is of conventional design. It serves to operate the oscillator 100' keying transistor Q20. The hold over oneshot 204 detects and turns on when the first pulse of a data record (header character described in FIG. 9 below) is received from computer 10. Each subsequent data pulse is detected and the hold over oneshot 204 is reset, holding the keying transistor Q20 off (oscillator 100' on) for a period of time while the oneshot 204 times out after the last data pulse is received. Level shifting and isolation components are conventional and will not be further discussed.

In an alternate embodiment, equivalent operation is obtained by omitting the hold over oneshot and connecting transistor Q20 directly to a second output port 202' on computer 10. The aforementioned

timing can then be accomplished by software means internal to computer 10.

FIG. 5 is a block diagram of the receiver system 116 used to convert the magnetic signals from the coil 102 of vehicle on-board computer 20 to electrical signals suitable for serial input to the host computer 112. A direct current electrical source (not shown) is supplied to power the receiver system 116.

While the basic functional requirements for transferring a signal which contains data from on-board computer 20 to host computer 112 may be accomplished by various equipment, the preferred embodiment illustrated is for a broad-band system with a unique combination of elements which reduce the effects of extraneous noise to minimize the subsequent passing of false information and random pulses to the host computer 112.

The broad-band technique utilized herein has a band width of approximately one-half octave centered on the nominal system frequency, to allow the on-board computer 20 to be equipped with a self-tuning output oscillator 100.

The "figure-eight" configuration of the input coil 114 is to eliminate sensitivity to radio signals and to electromagnetic noise emanating from sources beyond the intended zone of sensitivity, which normally extends to a few feet above the coil, along the coil axis.

The input device pickup coil 114, a resistor $R_L$ and a capacitor $C_L$ comprise a filter F1 centered on the nominal system frequency of the vehicle on-board computer 20 output coil 102. The input coil 114 inductance and capacitance are resonant at the nominal system frequency, and the resistance of the

resistor $R_L$ is approximately reactance of the capacitor $C_L$. This sets the Q of the resonant circuit to approximately 1, which is essentially a non-resonant circuit, but is in effect a broad band filter.

Filter F2 is a passive two-stage resistor-capacitor band pass filter centered on the nominal system frequency.

Filter F3 is a two-section low pass active filter of the Sallen-Key configuration set to have a gain of 10 at the nominal system frequency.

Filter F4 is a two-section high pass active filter of the Sallen-Key configuration set to have a gain of 10 at the nominal system frequency.

Amplifier A1 is a squaring amplifier equipped with positive feedback to provide high gain and hysteresis or "dead band." This type of circuit has the characteristics of a well known circuit known as a Schmitt Trigger. The purpose of amplifier A1 is to generate at its output a wave of standardized amplitude for any input signal with an amplitude exceeding a "dead band." Thus, small amplitude signals, such as most noise encountered, will not pass through amplifier A1. Thus amplitude discrimination, though not strictly filtering, is utilized to reject a class of unwanted signals.

Detector D1 is, in the preferred embodiment, simply a detector of the output signal of amplifier A1. D1, in conjunction with low-pass filter F5, converts the keyed on/off signal from the vehicle on-board computer 20 into a pulsed signal which duplicates the pulsed signal that initially was provided by output from the mobile monitoring apparatus 10.

It is important to note that the detector D1 may also be a frequency discriminator, to work with a vehicle on-board computer 20 output coil 102 using frequency shift keying (FSK), a form of frequency modulation. Such a configuration would take advantage of the inherent property of frequency shift keying and frequency modulation to override interfering noise. Such a configuration would be used in locations where the background noise level exceeds the noise rejection capability of the above-described system.

Amplifier A2 translates the signal from filter F5 to signal strength levels suitable for connection to a computer serial interface. A balanced-line type of amplifier, a current mode interface, or a separate modem means (not shown) may be incorporated as needed to drive a long cable 118 between a fueling bay 160 and the host computer 112.

Where a receiver 106 is utilized with mobile apparatus 10 to detect, filter, and amplify digitally encoded signals for input to computer 20, the receiver 106 components and function may be accomplished by apparatus as illustrated for receiver 116.

In FIG. 6, essential components comprising on-board computer 20 are illustrated. The on-board computer 20 is susceptible to a wide variety of suitable configurations. While the necessary hardware may utilize any number of commercially available portable computing units, it may be desirable to provide custom designed components to minimize cost, or to satisfy size requirements or other design constraints. Incoming sensor signals are transmitted to on-board computer 20 via signal transmission lines 210, 210', etc. Lines 210, 210', etc., are operatively connected to

input ports 214, 214', etc., as required to input signals from sensors 30 to IMS on-board computer 20. From the input ports 214, 214', etc., signals are fed to an input buffer 220, which in a simplified embodiment may be completely provided by software programming.. Upon command, a data bus 222 transports these signals to the microprocessor 224. A resident programmable read-only-memory (ROM) 226 is provided containing the resident program instructions, various constants, calibration constants, and clock setting functions. A memory device such as RAM (random access memory) 228 is comprised of data storage registers 230 with sufficient memory space for accumulated data. Data and instructions are transferred between the microprocessor 224, ROM 226 and RAM 228 via data bus 232. For transferring digitally encoded signals from the on-board computer 20 to external devices, communication ports, e.g., 240, 240', 240'', etc., are provided in sufficient number to accommodate various output devices desired in a particular application. As a minimum, one communication port 240 is operatively connected to output oscillator 100 which in turn is operatively connected to coil 102.

In enhanced embodiments, on-board computer 20 may be configured such that resident computer software program instructions are provided by receipt of programming instructions from the host computer 112, via coil 102 and 114. In such an embodiment, the on-board computer 20 may be configured so that a program memory library 242 is initially stored in the RAM 228, and thus this program library 242 can be reconfigured to redefine resident programs as desired. In yet another embodiment, a low cost configuration of on-board

computer 20 is achieved by providing the resident program calibrations and required instructions by use of a replaceable PROM semiconductor chip 226, which may contain a resident library 243. Thus, if instructions are to be changed, this could be quickly done by changing out PROM chip 226.

FIG. 7 illustrates an on-board computer 20 in its most elementary embodiment. Only instructions and data contained in a pre-programmed EPROM (erasible programmable read only memory) chip 250 are capable of being utilized. Upon receipt of an engine off signal, such as from engine status sensor 50, on-board computer 20 is switched from a standby condition to an operative condition. Clock timer/oscillator 252 initiates operation of EPROM 250, and pre-programmed data contained in EPROM 250 (typically vehicle identification numbers, with accounting and fuel requirements data optional) are transmitted via power oscillator 100 and coil 102. For those operations where it is undesirable to shut down the engine of machinery 16 in order to transmit authorization or identification codes, a pseudo engine off switch 253 may be provided for use by operator 18.

FIG. 8 illustrates optional equipment for use at remote locations. Remote base installations are configured basically in the same manner as a fixed base apparatus 12 described above; however, non-essential functions are omitted. Remote base apparatus 254 is comprised of remote base computer 255, connected to receiver 256, which in turn is connected to coil 114a. In many installations, an output power oscillator 257 will be desirable. Optional elements may include a modem 258, and a radio communication device such as

radio or cellular phone 259. Other optional elements include a security gate controller 260 which can be energized, upon receipt by computer 255 of an authorized identification code to open security gate 261.

Thus, remote base apparatus 254 may be engaged to control access to a remote location, by automatically opening and closing a gate as authorized vehicles 16 arrive and depart. One particularly useful application of this apparatus is to determine the entry and exit of properly instrumented vehicles 16 to and from roadways where fuel taxes are applicable, such as forest roads, mining roads, or other private roads.

In a basic embodiment of mobile apparatus 10, the on-board computer 20 can be configured to transmit an identification signal. Transmission of an identification signal can be initiated by any convenient means, such as by receipt of a signal from pseudo-engine off signal 253, which may be generated at a keypad or by a separatea simple switch. Thus a remote computer can easily be programmed to accumulate a record of vehicles 16 which pass over coil 114 or 114a. Such a configuration may be utilized in identification of vehicles while moving, also, such as may be desirable for an electronic license plate monitoring system.

In enhanced embodiments of mobile apparatus 10 and remote apparatus 254, a signal can be generated by remote apparatus 254 which provides a data record for storage in the memory of on-board computer 20. Items such as the location of the remote apparatus 254 and the date and time of passage of vehicle 16 may be recorded. This particular function creates a useful record of off-road activities and may be quite valuable to those fleet operators whose vehicles 16 are engaged in both

on-highway and off-highway use, and where fuel, road, or other tax reductions can be obtained provided records acceptable to applicable governmental authorities are maintained.

FIG. 9 graphically illustrates a data record 260 from a typical data stream. An entire data stream 262 consists of up to ten replicates of a data record 260. Thus, a data transmission may start and/or end with an incomplete data record 260. Furthermore, error correction may be accomplished by correlating two or more data records 260. The presence of an error in transmitted data is normally indicated by inequality between a check-sum addition and the check-sum field 264 valve. Other well known error checking and/or error correction coding processes may be utilized.

Data is transmitted with sequence header 266 first, trailer 268 last. The header field 266 consists of a stream of uniform characters, generally the number "255" which when encoded as a binary number in a standard ASCII format consists of a single start bit pulse. In a preferred embodiment, the header mark 266 is non-standard ASCII format in that three to five stop bits are used while only one or two are standard. The receiving computer system, normally host computer 112, interprets the ASCII serial data record 260 by measuring the time between pulses, but needs to identify the start pulse of each character (ASCII byte). The internal programming logic of the host computer 112 is arranged for this function and the excess stop bits of the header 266 synchronize the data originating clock and the data receiving clock (contained in the on-board and fixed base computers) to ensure proper data record 260 detection.

The header 266 serves two other functions, the first being to identify the beginning of the record so the remaining data fields are interpreted in proper sequence. The second function arises when the data 260 is delivered to a tape recorder 138. The tape recorder 138 reel mechanism is normally controlled by detection of a signal to record in the manner similar to a voice actuated recorder. The data header 266 carries no specific information and tolerates being recorded with various distortion while the tape recorder 138 reel mechanism comes up to operating speed. Similarly, playback distortion of tape recorder 138 does not degrade the useful information, even if a tape recorder 138 is stopped between data records 260. When utilized, on-board tape storage unit 118 may be configured to function similarly. The end of header mark 274 is any character different than the header 266 character. The end of header mark 274 is shown separately here, but the end of header 274 may carry information properly considered part of the format ID 276.

Vehicle or machinery performance data requirements vary with the number and kind of sensors 30 connected to the vehicle or machinery 16. Since various machinery and vehicles 16 within a fleet will be differently equipped, the format identification 276 tells the central computer 112 how many bytes to expect, and the order of parameters. Adequate computer software programs may easily be provided by those skilled in the art to enable data storage, processing, and data transfer as generally described herein.

Vehicle identification data 278 and accounting data 280 are the primary data needs which are reliably

provided by the system of the present invention. They are used to provide access authority to fuel dispensing station 150, to security gates 142, or other controlled areas or functions. They may also be used to properly identify accounting charges for various groups and sub-groups, or between various projects or clients, etc.

The remaining fields 282, 284, 286, etc., are reserved for the operational data gathered from the vehicle sensors 30 which vary with each specific application. As illustrated, data field 282 contains data for distance travelled (as processed from distance totalizing sensor 38), data field 284 contains data for engine hours (as processed from engine status sensor 50), and data field 286 contains data from other sensors 30.

Check-sum field 264 is the sum of all the previous bytes from the end of header mark 274. The arithmetic used by the transmitting computer (normally on-board computer 20) to make up the check-sum field 264 is duplicated in the receiving computer (normally host computer 112) and compared with the transmitted check-sum 264. Equality between check sum field 264 and the sum calculated by the receiving computer is evidence of no errors.

Trailer 268 is a short sequence of blanks and is used to help ensure that the analyzing program can identify and return to data filing at the header 266 in the event of loss of data. It also provides time for a tape recorder 138 to coast to a stop between data records 260 when recorded data is used.

As briefly mentioned above, one mode of operation of the on-board computer 20 would be to automatically trigger the transmission of data

stream 260 at the time that engine status sensor 50 detects an engine off condition. Alternatively, when it is inappropriate for the engine of machinery 16 to be turned off, a pseudo-off signal device 253 may be utilized to begin the data off-loading operation. The signal device 253 will typically be most useful at a security gate 142 or at a remote base location 254. Normal practice of initiating off-loading of data stream 260 only upon shutdown of the machinery 16 can help prevent the dispensement of fuel under hazardous conditions. Also, the amount of fuel actually loaded on board could be compared to the anticipated maximum amount required, and any discrepancies which arise may be noted by programs in host computer 112 for automatic reporting to management.

In general, data transmission only needs to be from machinery 16 to the fixed base host or central computer system 112. This approach is sufficient for most data recording and device authorization/actuation activities. However, in a number of applications, it is helpful to also have an input capability to the on-board computer 20. This can ease the computer system maintenance requirements by initializing the on-board computer, changing pre-set parameters, changing identification or accounting codes, etc. Therefore, the coil 102, and pertinent components of power oscillator 100 and on-board computer 20 may be configured with suitable circuitry to act as a receiving antenna at the same frequency when coil 102 is not transmitting. This technique is the well known "half duplex" communication method used for communication in telephone, telegraph, and radio applications. With such a "half duplex" setup, the information management system

of the present invention can be very useful for "data output on demand" or "identification inquiry and acknowledgement" type applications.

Referring now to FIGS. 10 through 14, in many cases the components of structures are essentially duplicates of what is shown in FIG. 10. To the extent that this is true, like reference characters have been employed for like purposes. In FIG. 10, one configuration for signal acquisition from fuel feed flow sensor 32 and from fuel return flow sensor 34 is illustrated. In diesel powered machinery 16, fuel tank 300 contains fuel 302. Fuel moves through line 304, through meter 32, and through line 308, by action of fuel pump 310. Fuel then flows through line 312 to diesel engine 314, where it is circulated in an "injector rail" or loop 316 for supplying fuel to injectors 318. Fuel which is not consumed escapes through a pressure reduction orifice 319 and returns through line 320 to return fuel flow sensor 34, thence through line 324 to fuel tank 300.

Since a substantial portion of fuel 302 supplied to engine 314 is not consumed in any one pass, but rather is returned to the fuel tank 300, a measurement of fuel 302 supplied such as done by meter 32 alone, will not provide a true indication of the amount of fuel 302 consumed. In addition, a common problem is that in loop 316 the fuel 302 gains heat, generating bubbles which interfere with return fuel flow sensor 34. In a conventional system as known in the art, bubbles and gases return through line 324 and escape from fuel tank 300 via fuel/vent cap 326.

Referring now to FIG. 11, an improved method for acquiring fuel flow data in a diesel engine 314

system is depicted. In the system illustrated, a single fuel flow meter is utilized. Fuel tank 300 having a vent and fill pipe 326 is shown containing fuel 302. A feed line 304 connects the fuel tank 300 with fuel flow meter 32. From meter 32, fuel line 308 proceeds to a "tee" 309 where fuel lines 308, 328, and 329 intersect. Fuel 302 continues to flow through line 329 to pump 310, thence through injector rail 316. The fuel pump 310 supplies the pressure differential required to move fuel 302 from the fuel tank 300 through the engine injector rail 316 and return through fuel line 320 to debubbling device 330. Return fuel line 320 contains return flow of fuel 302 containing gas bubbles.

Debubbling unit 330 is a closed vessel having inlet at fuel line 320, a degassed fuel outlet 328, and an overflow and vapor outlet line 331 which returns to fuel tank 300. Degassed fuel exiting through line 328 at the bottom of debubbler 330 mixes with fuel 302 flowing to the "tee" 309 mixing point via line 308, and a blended fuel mixture flows through fuel line 329 to supply engine 314.

Debubbling device 330 contains a plurality of perforated trays including trays 332, 334, and 336. Liquid fuel and bubbles entering the debubbler 330 via line 320 impinge upon an initial perforated tray 332. Liquid fuel 302 is able to fall via gravity through subsequent baffles 334 and 336 downward through the debubbling device 330. Vapor from bubbles which escapes the liquid rises through apertures 342, 344, 346, and 348, etc., and escapes upward toward the top of the debubbler 330. Although a simple fabrication method for a debubbler 330 results in a cylindrical configuration, the device can also be conveniently fabricated in other

shapes. Liquid accumulates in the debubbling device 330 establishing a liquid level 349, and float 350 is eventually lifted via buoyancy provided by fuel 302 in the debubbler 330. Float 350 has an attached shaft 352 connected to an outlet valve 354. Valve 354 is positioned on valve seat 358, so that when the float 350 is not raised, a seal is formed between valve 354 and valve seat 358. When there is sufficient fuel 302 in debubbler 330, float 350 rises and valve body 354 disengages from valve seat 358 to permit fuel 302 in debubbler 330 to enter line 329 via "tee" 309. As fuel 302 containing bubbles continues to enter the debubbler tank 330 via fuel line 320, the pressure will expell gases 302 out line 331. Thus, due to this feature and unlike prior devices, this simple debubbling device 330 can be located at any convenient position. The vertical elevation of the debubbling device 330 is not critical.

Line 331 must contain a "seal leg" so that the elevation of line 331 at some point at least rises above the maximum liquid level 303 of fuel 302 in fuel tank 300, so that fuel does not flow out of tank 300 and into debubbler 330 by force of gravity. Alternately, a suitable check valve could be provided.

FIG. 11 also shows details of the debubbling device 330. Optionally, a heat exchanger 380 may be provided to cool fuel 302 flowing through line 320 by exchanging heat with an impinging stream of air 382. The location of the two-phase fuel/vapor flow line 320 is such that fuel flow impinges on perforated baffles 332, 334, and 336. The vapor exit line 331 is located at a high elevation point in the debubbling

vessel 330 so that only vapor will escape through line 331.

Referring now to FIG. 12, it is to be noted that debubbler 330 may be used as a gas/vapor separator in a two-meter system to bypass the disengaged gases around a return flow fuel measuring meter 34. This system is an improvement over the system utilizing the meter 34 alone as shown in FIG. 11. As shown in FIG. 12, returning fuel 302 from the injector rail 316 enters debubbler tank 330 via pipe 320. Bubble separation occurs as described above. Fuel 302 leaves the debubbling tank 330 via pipe 384 and enters meter 34. Separated gas is sent from debubbler 330 around the meter 34 via line 331, and re-enters the fuel tank 300 directly. In this embodiment, the float 350 ensures that the outlet valve port 358 in the top of debubbler 330 is always sealed during a high liquid level. Float 350 level fluctuates as engine fuel requirements change. In the event the meter 34 restricts fuel flow due to failure or to presence of foreign material, fuel 302 will fill the debubbling tank 330 and impose back pressure on pump 310 until excessive pressure opens a bypass loop (not shown), allowing fuel to reach the fuel tank.

In the configuration illustrated in FIG. 12, fuel 302 is removed from the tank 300 via fuel line 304. It is to be noted that fuel metering means 32 can be provided by positive displacement pump 310' thus eliminating the need for both a pump 310 and a separate meter 32. The choice of one meter 32 as shown in FIG. 11, or two meters as shown in FIG. 12 (provided in each case with separator 330 and vapor bypass means or inclusion of a return fuel line heat exchanger) is a

function of engine characteristics, mounting space, cooling requirements and economics. If a separate meter 32 is desired, the fuel feed meter 32 should be located upstream of pump 310 in line 308.

As illustrated in FIG. 12, fuel flow, i.e., fuel 302 consumed by the engine 314, is reliably determined by taking the difference between fuel input via meter 32 and the output fuel flow meter 34. The difference between the two meter readings is the fuel consumed by engine 314. This differencing determination may be done by a separate external differencer or via programming instructions in the on-board computer 20. It is to be noted, however, that where two phase flow is observed in line 320 as, for example in the configuration illustrated earlier in FIG. 10, fuel meter 34 may not provide a reliable indication of actual fuel returned to the fuel tank.

A further improvement in fuel measurement can be achieved by minimizing or eliminating bubbles in fuel return line 320. In a typical diesel engine system, fuel is pressurized while circulating in a supply loop 316 for feeding fuel to injectors 318. Pressure in supply loop 316 is nominally 30 to 60 psig, or higher. This pressure is maintained by a small orifice 319 located at the exit of loop 316, as shown generally in FIGS. 10-12. At orifice 319, cavitation bubbles are formed as pressure of fuel is decreased. Thus, fuel entering line 320 may have moderate entrainment of bubbles, or, in some cases, return line 320 contents may be virtually foam.

It is believed that the bubble formations often observed in diesel engine systems is at times due to the operation of orifice 319 itself. In many cases,

the fluid flow velocity through the restriction orifice 319 is sufficiently high that the localized static pressure falls below the vapor pressure of at least some components of the heated diesel fuel. Bubbles thus formed mix with liquid fuel to create a foamy return fuel flow in line 320.

We have now discovered that by replacing orifice 319 with a well designed venturi 390, adequate flow restriction can be maintained to insure that necessary pressure is maintained in fuel supply loop 316 while avoiding formation of bubbles in line 320. Several benefits result. First, the requirement for debubbling equipment in the fuel return system is reduced. Second, volatile organic carbon (VOC) emissions from vehicle debubbler vent stacks as present in many known devices are eliminated. Alternately, such VOC emissions from fuel tank vents are eliminated. Also, since a venturi 390 can be utilized for reliable measurement of return fuel flow, pressure reduction and fuel measurement devices can be accomplished simultaneously.

Designs for workable venturis 390 are illustrated in FIG. 11 and 12. In FIG. 13, venturi 390 is provided with a smoothly curved convergent face 394. Throat 392 has diameter "D". The radius of curvature of the convergent face should be approximately 2D. A smooth divergent section 396 is provided with a wall angle alpha ($\alpha$) not more than 7.5° from the flow axis, gradually enlarging until a smooth, straight outer wall of desired diameter of return line 320 is reached.

FIG. 14 shows a similar venturi device 397 with slightly different geometry. In venturi 397, the convergent zone is a smoothly sloped sidewall 394 with

an inward wall angle beta ($\beta$) not exceeding 11° from the axis of flow. The divergent zone 396 is a smoothly sloped sidewall with an outer angle delta ($\delta$) not exceeding 3° from the flow axis. The divergent zone 396 gradually enlarges until a smooth, straight outer wall of desired diameter of return line 320 is reached.

In summary, although various apparatus may be utilized to improve reliability of sensor information, or to reduce auxiliary equipment required to obtain reliable information of parameters such as fuel flow, the report generation function is at the heart of the utility of the present invention. Data reports can enable managers to supervise and control fleet maintenance procedures, can provide indicators of performance of machinery operators 18 and thereby direct management activities aimed at improving operator 18 performance, and can allow management to engage in programs which will enable productivity of both equipment 16 and operators 18 or other personnel. For example, by automatically differentiating between on-road and off-road use, the system of the present invention will automatically create an audit trail that fleet operators can present to governmental authorities. Such a record of use may provide an immediate savings for fleet operators who at present may have only general estimates of non-taxable fuel use which may be unacceptable to tax auditors.

The system according to the present invention is clearly an improvement over a punch card system, magnetic card system or optical bar code system, where the driver 18 has to locate his authorization device, or enter identification numbers, to make his fuel request. Usual problems of prior devices, such as dirty or worn

cards, or forgotten identification and authorization codes, are eliminated in the present invention. Thus, loss of productive labor is minimized. Also, in the present invention, the entire data transfer process occurs automatically, without the need for operator interaction. Thus, one advantage of the present invention is to relieve the driver of any workload requirements in dealing with an information management system. In fact, the present invention is intentionally directed toward enabling fleet operators to eliminate data input requirements by operators so as to minimize the possibility of errors, and to create an information management system that is tamper resistant, in order to eliminate unauthorized data modification or data purging. Normally, the on-board computer 20, output oscillator 100, and coil 102 are provided in a sealed, tamper resistant box, to prevent unauthorized modification. Since authorization codes can be set up and controlled so as to be known only by computers 20 and 112 (and the computer programmer), access to secured areas and activities can be effectively controlled. Thus, risk that facility or system security may be compromised by authorization codes falling into the wrong hands is effectively eliminated.

Another use of the present invention is to utilize the accounting registers 280 within data record 260 to identify billing sequences and to automatically bill authorized accounts, or to debit funds from accounts as authorized. Thus, the apparatus and method of the present invention, utilizing information exchanged between the on-board computer 20 and a host computer 112, could eliminate the need for credit cards or cash in fueling transactions, while

allowing automatic accounting and billing for the actual fuel or other metered service provided.

Yet another use for the present invention is for accident reconstruction. In an extensively instrumented vehicle 16, containing many different types of sensors 30, the data records kept by the on-board computer 20 will allow evaluation of the vehicle performance data prior to an accident. Depending upon the degree of memory space provided in on-board computer 20, performance data on a variety of parameters may be saved for later analysis on a very small time scale, such as once every second, or less. Normal operation of on-board computer 20 is to save data sets in data registers, then to process accumulated data sets on a periodic basis to create condensed reports for management. Accident analysis can simply make use of the most recent raw data sets which have been accumulated for performance monitoring reporting.

The present invention also allows a complete record to be generated of interactions of equipment operators 18 with their machinery 16 during normal operations. Trends, rates, and averages, can be developed for both entire fleets and for particular operators 18. When such data is evaluated within a data set for a particular type of operation, it may provide excellent indicators as to activities or operations which may tend to endanger equipment 16 or which may present an unreasonable risk of harm to either the operator 18, the equipment 16, or to the public. For example, a correlation of engine RPM sensor 40 output with clutch operation sensor 42 may be used to identify operators which repeatedly engage in "high engine revolution shifting." Output from speed sensor 36 can

be correlated by hours of operation or by percent of operational hours at various speed ranges to identify drivers who operate at excessive speed, or who are idle for extended periods.

Another useful operational indicator is the number of brake pushes, as indicated by brake position sensor 44, correlated with data from speed sensor 36, to provide a listing of brake pushes at various ranges of speed. Also, fuel consumption within various speed ranges can also be compiled for evaluation. Examples of reports which can be readily prepared by way of the present invention are set forth in Tables I, II, and III.

TABLE I - INFOMASTER DATA SUMMARY
Total Basis: Start to Time Y

| )CATION: | Bellevue, WA | Eugene, OR | Glendale, CA | Los Angeles, CA | Pasadena, CA | Claremont, CA |
|---|---|---|---|---|---|---|
| .TE: | 10/14/88 | 10/13/88 | 10/10/88 | 10/10/88 | 10/10/88 | 10/09/88 |
| ME: | 18:59 | 18:14 | 15:02 | 12:48 | 09:24 | 14:16 |
| :H IDENT | 3. | 3. | 3. | 3. | 3. | 3. |
| EL TYPE | 0 | 0 | 0 | 0 | 0 | 0 |
| LES TRAVELED | 2878.00 | 2564.30 | 1468.80 | 1459.00 | 1446.70 | 1354.00 |
| ,OCK | 674.57 | 649.80 | 574.63 | 572.99 | 569.59 | 549.77 |
| IGINE HOURS | 63.22 | 57.23 | 33.86 | 33.47 | 32.79 | 28.85 |
| :O WORKING HOURS | 6.63 | 6.33 | 4.72 | 4.62 | 4.36 | 3.35 |
| .CH HOURS @ 1800 RPM | N/A | N/A | N/A | N/A | N/A | N/A |
| LLONS OF UNTAXABLE FUEL* | 8.90 | 8.40 | 6.50 | 6.30 | 5.90 | 3.80 |
| LLONS OF TAXABLE FUEL | 248.50 | 222.30 | 129.20 | 128.40 | 127.20 | 117.80 |
| AKE APPLICATIONS | 1475.00 | 1390.00 | 838.00 | 816.00 | 774.00 | 501.00 |
| )URS AT: | | | | | | |
| .1 to 5 MPH | 1.66 | 1.54 | 1.03 | .98 | .90 | .57 |
| 5 to 15 MPH | 2.17 | 2.03 | 1.09 | 1.06 | 1.02 | .66 |
| 15 to 25 MPH | 2.38 | 2.22 | 1.33 | 1.30 | 1.22 | .72 |
| 25 to 35 MPH | 2.59 | 2.45 | 1.62 | 1.60 | 1.53 | 1.01 |
| 35 to 45 MPH | 2.80 | 2.66 | 1.58 | 1.56 | 1.56 | 1.27 |
| 45 to 55 MPH | 10.26 | 9.61 | 4.26 | 4.18 | 4.10 | 3.68 |
| 55 to 60 MPH | 19.93 | 18.13 | 9.66 | 9.60 | 9.54 | 9.09 |
| 60 to 65 MPH | 13.55 | 11.27 | 7.98 | 7.98 | 7.97 | 7.91 |
| 65 to 70 MPH | 1.25 | .99 | .59 | .59 | .59 | .59 |
| over 70 MPH | .00 | .00 | .00 | .00 | .00 | .00 |
| AKE PUSHES AT: | | | | | | |
| .1 to 5 MPH | 401.00 | 372.00 | 244.00 | 236.00 | 217.00 | 149.00 |
| 5 to 15 MPH | 343.00 | 333.00 | 193.00 | 190.00 | 183.00 | 116.00 |
| 15 to 25 MPH | 328.00 | 301.00 | 182.00 | 175.00 | 167.00 | 97.00 |
| 25 to 35 MPH | 249.00 | 238.00 | 143.00 | 142.00 | 134.00 | 80.00 |
| 35 to 45 MPH | 96.00 | 91.00 | 52.00 | 51.00 | 51.00 | 40.00 |
| 45 to 55 MPH | 45.00 | 43.00 | 19.00 | 17.00 | 17.00 | 14.00 |
| 55 to 60 MPH | 8.00 | 8.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| 60 to 65 MPH | 3.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 65 to 70 MPH | 2.00 | 2.00 | .00 | .00 | .00 | .00 |
| over 70 MPH | .00 | .00 | .00 | .00 | .00 | .00 |
| ALLONS AT: | | | | | | |
| .1 to 5 MPH | 1.70 | 1.60 | 1.10 | 1.10 | 1.10 | .70 |
| 5 to 15 MPH | 2.30 | 2.20 | 1.50 | 1.50 | 1.50 | 1.00 |
| 15 to 25 MPH | 4.50 | 4.20 | 2.20 | 2.10 | 2.10 | .50 |
| 25 to 35 MPH | 7.80 | 7.50 | 4.50 | 4.40 | 4.10 | 2.80 |
| 35 to 45 MPH | 11.10 | 10.50 | 6.50 | 6.40 | 6.30 | 5.00 |
| 45 to 55 MPH | 47.60 | 45.60 | 23.00 | 22.70 | 22.10 | 19.70 |
| 55 to 60 MPH | 98.10 | 88.60 | 47.30 | 47.30 | 47.20 | 45.50 |
| 60 to 65 MPH | 68.10 | 56.70 | 39.90 | 39.70 | 39.60 | 39.40 |
| 65 to 70 MPH | 7.20 | 5.30 | 3.10 | 3.10 | 3.10 | 3.10 |
| over 70 MPH | .10 | .10 | .10 | .10 | .10 | .10 |

:When PTO equipped.

TABLE II - INFOMASTER DATA SUMMARY
Differential Basis: Time X to Time Y

| ATION: | Eugene to Bellevue | Glendale to Eugene | Los Angeles to Glendale | Pasadena to Los Angeles | Claremont to Pasadena | Claremont, CA |
|---|---|---|---|---|---|---|
| TE: | 10/14/88 | 10/13/88 | 10/10/88 | 10/10/88 | 10/10/88 | 10/09/88 |
| ME: | 18:59 | 18:14 | 15:02 | 12:48 | 09:24 | 14:16 |
| H IDENT | 3. | 3. | 3. | 3. | 3. | 3. |
| LLONS LOADED | N/A | N/A | N/A | N/A | N/A | N/A |
| EL TYPE | 0 | 0 | 0 | 0 | 0 | 0 |
| LES TRAVELED | 313.70 | 1095.50 | 9.80 | 12.30 | 92.70 | |
| OCK | 24.77 | 75.17 | 1.64 | 3.40 | 19.82 | |
| GINE HOURS | 5.99 | 23.37 | .39 | .68 | 3.94 | |
| O WORKING HOURS | .30 | 1.61 | .10 | .26 | 1.01 | |
| CH HOURS @ 1800 RPM | N/A | N/A | N/A | N/A | N/A | |
| LLONS OF UNTAXABLE FUEL* | .50 | 1.90 | .20 | .40 | 2.10 | |
| LLONS OF TAXABLE FUEL | 26.20 | 93.10 | .80 | 1.20 | 9.40 | |
| AKE APPLICATIONS | 85.00 | 552.00 | 22.00 | 42.00 | 273.00 | |
| URS AT: | | | | | | |
| .1 to 5 MPH | .12 | .51 | .05 | .08 | .33 | |
| 5 to 15 MPH | .14 | .94 | .03 | .04 | .36 | |
| 15 to 25 MPH | .16 | .89 | .03 | .08 | .50 | |
| 25 to 35 MPH | .14 | .83 | .02 | .07 | .52 | |
| 35 to 45 MPH | .14 | 1.08 | .02 | .00 | .29 | |
| 45 to 55 MPH | .65 | 5.35 | .08 | .08 | .42 | |
| 55 to 60 MPH | 1.80 | 8.47 | .06 | .06 | .45 | |
| 60 to 65 MPH | 2.28 | 3.29 | .00 | .01 | .06 | |
| 65 to 70 MPH | .26 | .40 | .00 | .00 | .00 | |
| over 70 MPH | .00 | .00 | .00 | .00 | .00 | |
| AKE PUSHES AT: | | | | | | |
| .1 to 5 MPH | 29.00 | 128.00 | 8.00 | 19.00 | 68.00 | |
| 5 to 15 MPH | 10.00 | 140.00 | 3.00 | 7.00 | 67.00 | |
| 15 to 25 MPH | 27.00 | 119.00 | 7.00 | 8.00 | 70.00 | |
| 25 to 35 MPH | 11.00 | 95.00 | 1.00 | 8.00 | 54.00 | |
| 35 to 45 MPH | 5.00 | 39.00 | 1.00 | .00 | 11.00 | |
| 45 to 55 MPH | 2.00 | 24.00 | 2.00 | .00 | 3.00 | |
| 55 to 60 MPH | .00 | 5.00 | .00 | .00 | .00 | |
| 60 to 65 MPH | 1.00 | .00 | .00 | .00 | .00 | |
| 65 to 70 MPH | .00 | 2.00 | .00 | .00 | .00 | |
| over 70 MPH | .00 | .00 | .00 | .00 | .00 | |
| LLONS AT: | | | | | | |
| .1 to 5 MPH | .10 | .50 | .00 | .00 | .40 | |
| 5 to 15 MPH | .10 | .70 | .00 | .00 | .50 | |
| 15 to 25 MPH | .30 | 2.00 | .10 | .00 | 1.60 | |
| 25 to 35 MPH | .30 | 3.00 | .10 | .30 | 1.30 | |
| 35 to 45 MPH | .60 | 4.00 | .10 | .10 | 1.30 | |
| 45 to 55 MPH | 2.00 | 22.60 | .30 | .60 | 2.40 | |
| 55 to 60 MPH | 9.50 | 41.30 | .00 | .10 | 1.70 | |
| 60 to 65 MPH | 11.40 | 16.80 | .20 | .10 | .20 | |
| 65 to 70 MPH | 1.90 | 2.20 | .00 | .00 | .00 | |
| over 70 MPH | .00 | .00 | .00 | .00 | .00 | |

When PTO equipped.

TABLE III - INFOMASTER DATA SUMMARY
Total Basis: Start to Time Y

| | |
|---|---|
| DATE: | June 1, 1988 |
| DAY: | Wednesday |
| TIME: | 17:10 |
| VEHICLE IDENT: | 8 |
| PUMPSITE: | 10th Street Facility |

| Hours | Present | Previous |
|---|---|---|
| Clock hours | 102.18 | 0.00 |
| Engine hours | 14.73 | 0.00 |
| Non-moving hours | 3.17 | 0.00 |
| Moving 0 to 2 MPH | 3.17 | 0.00 |
| Moving 2 to 10 MPH | 1.58 | 0.00 |
| Moving 10 to 20 MPH | 1.02 | 0.00 |
| Moving 20 to 40 MPH | 3.28 | 0.00 |
| Moving 40 to 55 MPH | 4.09 | 0.00 |
| Moving 55 to 60 MPH | 1.50 | 0.00 |
| Moving 60 to 70 MPH | 0.09 | 0.00 |
| Moving over 70 MPH | 0.00 | 0.00 |
| Odometer | 34,455.0 | 34,036.9 |
| Miles traveled | 418.1 | 0.0 |
| MPH average | 28.4 | 0.0 |
| RPM average | 2128 | 0.00 |
| Gallons used | 39.4 | 0.00 |
| GPH average | 2.7 | 0.00 |
| MPG average | 10.6 | 0.00 |
| Fuel type<br>0 = gasoline | 0 | 0 |
| Gallons loaded | 39.3 | -------- |

It can clearly be seen that performance monitoring according to the present invention will allow fleet operators to identify training needs, discipline needs, and will inevitably enable fleet operators to reduce direct operating costs, reduce losses, and provide for reduced insurance rates. Also, such monitoring can provide management with the necessary information to evaluate equipment utilization ratios, to enable the operation and maintenance practices to be improved, and life of machinery to be cost effectively extended. Thus the convenient availability of a multitude of machine 16 performance and human operator 18 performance data can provide managers with information which is quite valuable in reducing direct operating expenses.

From the foregoing it can be seen that the herein described method and apparatus for mobile equipment identification and performance monitoring provides an easily used device which reliably performs the desired vehicle identification and monitoring tasks. Utilizing the magnetic inductive coupling technique for communication of data, transfer of identification and monitoring data is reliable, without interference, and occurs automatically. Also, improved fuel use measurements can be achieved by utilizing the fuel measurement techniques taught by the present invention. The apparatus and methods of the present invention are especially useful in trucking fleets, in bus transportation fleets, and for hazardous chemical transportation fleets, but its application is not limited thereto.

It will be apparent after studying the drawings and reading the description of the various

embodiments that changes may be made in the arrangement and positioning of the components within the spirit and scope of the invention. Thus, the foregoing description of embodiments of the invention have been presented for purposes of illustration and description and for providing an understanding of the invention. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. On the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as expressed in the appended claims. Obviously, many modifications and variations are possible in light of the above teaching. The particular embodiments were chosen and described in some detail to best explain the principles of the invention and its practical application to thereby enable others skilled in the relevant art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Changes and modifications from the specifically described embodiments can be carried out without departing from the scope of the invention. It is intended that the scope of the invention be indicated by the appended claims rather than by the foregoing description; and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

CLAIMS

What is claimed is:

1. An identification, data storage and data transfer system for storing and transferring information from mobile machinery having associated with it detectable characteristics and at least one engine, said identification, data storage and data transfer system comprising:

an IMS (Information Management System) computer on-board said mobile machinery, said on-board computer having internal instructions stored therein and adapted to reliably store and make available for transmission digitally encoded data,

an output coil located on-board said mobile machinery, said output coil utilizing an alternative current at low power, said output coil being operatively connected with said on-board computer,

an IMS host computer,

an input coil operable to detect a lower power magnetic field created by said output coil, said input coil configured to receive digitally encoded data from said output coil, and said input coil operatively connected to provide said digitally encoded data to said IMS host computer,

said output coil being positioned by adjustment of the location of said mobile machinery in relation to said input coil so that an operative position is achieved wherein a magnetic inductive coupling effect is provided between said input coil and said output coil,

sensing means positioned to determine the status of said engine, said sensing means comprising

means to generate a signal corresponding to an engine inoperative condition,

said IMS on-board computer internal instructions including instructions to transmit data stored in said IMS on-board computer to said IMS host computer by reconfiguring said IMS on-board computer between:

a) a standby position wherein said IMS on-board computer stores data, and

b) an active position wherein said IMS on-board computer is engaged to transmit a continuously repeated digitally encoded identification signal to said output coil,

said reconfiguration of said on-board computer being initiated upon receipt of an engine inoperative signal from said engine status sensor.

2. The apparatus of claim 1, wherein said magnetic inductive coupling effect between said output coil and said input coil is operative at a distance from 0.5 feet to 10 feet between said output coil and said input coil.

3. The identification, data storage and data transfer apparatus set forth in claim 1 wherein said data stored in said on-board computer includes an identification code for said mobile machinery.

4. The apparatus of claim 3, wherein said data stored in said on-board computer further comprises a vehicle identification code, a fuel type code, and a fuel quantity limitation code.

5. The identification, data storage and data transfer apparatus set forth in claim 2 further including at least one secured area access device operatively connected to said host computer, said

secured area access device being activated by said host computer upon receipt of an authorized identification code.

6. The identification, data storage and data transfer apparatus set forth in claim 2 further including at least one fuel pump controller operatively connected to said host computer, said fuel pump controller being activated by said host computer upon receipt of an authorized identification code.

7. The identification, data storage and data transfer apparatus set forth in claim 4 further including an alarm means operatively connected to said host computer, said alarm means being activated when an unauthorized identification code is received by said host computer.

8. The apparatus of claim 3 wherein said data stored in said on-board computer further comprises a reference program library, said library including a malfunction reference data library program to determine if signals from said sensors exceed pre-determined values.

9. The apparatus of claim 2 wherein said data stored in said on-board computer further comprises accounting information for automatic debit transactions against an authorized account.

10. The apparatus of claim 2, wherein said engine of said mobile machinery consumes fuel, and wherein said mobile machinery is utilized in applications where said fuel is taxable by governmental authorities, and wherein said mobile machinery is additionally utilized in applications where said fuel is not taxable by said governmental authorities, wherein said apparatus further includes means for acquisition of

application type data to establish fuel tax status, said last mentioned means comprising:

a first sensor for providing an engine status signal,

a second sensor for providing accurate measurement of fuel supplied to said engine,

a clock means to provide time keeping data for cross reference to data reported by any of said first, second, or third sensors.

11. The apparatus of claim 10, wherein said mobile machinery has power takeoff equipment attached thereto, and wherein said means for acquisition of said application type data further includes a third sensor for providing an operational status signal for said power takeoff equipment.

12. The apparatus of claim 10, wherein said means for acquisition of said application type data further includes a third sensor, said third sensor providing a continuous measurement of fuel which is not consumed in said engine after having been supplied to said engine, and wherein said second sensor for fuel measurement provides a first signal and said third sensor for fuel measurement provides a second signal to said on-board computer, and wherein said first and second signals are compared to determine a true fuel consumption measurement for said engine.

13. The apparatus of claim 10, further including a remote base apparatus, said last mentioned apparatus including means for transmitting digitally encoded data, wherein said digitally encoded data provides information indicating a change in taxable status of fuel used by said mobile machinery.

14. A data acquisition, processing, storage, and transfer system for acquiring, storing, processing, and transferring information from mobile machinery with which a plurality of different detectable characteristics are located, comprising:

one or more IMS (Information Management System) on-board computers, said computer including means to receive data, means to store data, and means to communicate data to another computer,

sensors positioned to acquire one or more said detectable characteristics and generate a signal therefrom,

means for conversion of said signal into digitally encoded data,

raw data transportation means, operatively connected between said signal conversion means and said IMS on-board computer, adapted to reliably transfer said digitally encoded data from said signal conversion means to said IMS on-board computer,

on-board data transceiving coil located on-board said mobile machinery, said coil being operable to alternately emit and detect a low power magnetic field, said on-board transceiving coil being operatively connected with said on-board computer,

processed data transportation means, operatively connected between said IMS on-board computer and said on-board data transceiving means,

one or more IMS host computers, fixed base data transceiving coil operable to alternately emit and detect a low power magnetic field, said fixed base transceiving coil configured to receive digitally encoded data from said on-board computer, and

operatively connected to provide said digitally encoded data to said IMS host computer,

said on-board transceiving coil being positioned by adjustment of the location of said mobile machinery in relation to said fixed base transceiving coil so that an operative position is achieved wherein a magnetic inductive coupling effect is provided between said on-board coil and said fixed base coil,

fixed base processed data transportation means, operatively connected between said fixed base transceiving means and said IMS host computer,

said IMS on-board computer having internal instructions stored therein providing for:

a) data storage means,

b) data receiving means adapted to receive

i) digitally encoded data from said sensors,

ii) instructions from input means,

iii) commands from said IMS central computer,

c) data transmission means adapted to provide data output to said IMS central computer response thereto,

d) operating system means adapted to execute internal instructions in response to instructions received from

i) input means,

ii) said IMS central computer,

e) comparator means adapted to determine whether or not data values received by said IMS on-board computer are within normal limit values stored within said IMS on-board computer,

said IMS on-board computer adapted to communicate with said IMS host computer by reconfiguring said IMS on-board computer communications means between:

a) a standby position wherein said IMS on-board computer is ready to receive an AT (attention) signal provided by said IMS host computer, and

b) an active position wherein said IMS on-board computer is engaged to communicate

i) an AK (acknowledgement and identification) signal to said IMS host computer, and

ii) said processed data to said IMS host computer upon receipt of a command to output said data to said IMS host computer.

15. The apparatus of claim 14, further comprising a system for degassing heated fuel in a fuel return line of a diesel engine, said system comprising a fuel return line through which unburned fuel returns from said engine, a degassing vessel having a fuel inlet, a fuel outlet, and a vapor outlet, said fuel inlet communicating with said fuel return line, said fuel outlet communicating with a fuel tank on said mobile machinery, and said vapor outlet communicating with said fuel tank on said mobile machinery, said degassing vessel containing a plurality of baffles to disengage vapors from liquid fuel entering said degassing vessel, said degassing vessel containing a float means and a valve means, said float means responsive to a predetermined fuel level in said degassing vessel so as to operate said valve means and thereby prevent gas escapement into said fuel outlet line.

16. A vehicle data acquisition and recording system for supplying retrievable digitally encoded

signals representative of a plurality of vehicle performance sensor signals, said plurality of vehicle performance sensor signals including analog signals and discrete signals, said vehicle data acquisition and recording system comprising:

an IMS on-board computer unit having a plurality of input ports, each input port being connected for receiving one of said vehicle performance sensor signals, said on-board computer including means for accessing selected ones of said vehicle performance sensor signals and for processing each accessed signal in response to an internal program instruction, said on-board computer unit further including means for storing a digitally encoded signal representative of each vehicle performance sensor signal;

a host computer for receiving each of said digitally encoded signals supplied by said on-board computer, said host computer being responsive to program instructions to detect the time at which a plurality of predetermined procedures are undertaken, said host computer further being responsive to program instructions to process said digitally encoded signals supplied by said on-board computer;

programmed memory means for storage of said program instructions, said programmed memory means being operatively connected to said host computer, and adapted to acquire, store, and sequentially evaluate selected specific vehicle performance sensor signals, and

an output coil located on-board said vehicle, said output coil being operable to emit a lower power magnetic field, said output coil being operatively connected with said on-board computer,

an input coil operable to detect a low power magnetic field, said input coil configured to receive digitally encoded data from said on-board computer, and operatively connected to provide said digitally encoded data to said host computer,

said output coil being positioned by locating said vehicle in relation to said input coil so that an operative position is achieved wherein a magnetic inductive coupling effect is provided between said input coil and said output coil.

17. The apparatus of claim 16, further comprising a system for degassing heated fuel in a fuel return line of a diesel engine, said system comprising a fuel return line through which unburned fuel returns from said engine, a degassing vessel having a fuel inlet, a fuel outlet, and a vapor outlet, said fuel inlet communicating with said fuel return line, said fuel outlet communicating with a fuel tank on said mobile machinery, and said vapor outlet communicating with said fuel tank on said mobile machinery, said degassing vessel containing a plurality of baffles to disengage vapors from liquid fuel entering said degassing vessel, said degassing vessel containing a float means and a valve means, said float means responsive to a predetermined fuel level in said degassing vessel so as to operate said valve means and thereby prevent gas escapement into said fuel outlet line.

18. The apparatus of claim 15, further including a pressure reducer in said return fuel line of said diesel engine, where said pressure reducer is a venturi.

18. The apparatus of claim 15, further including a pressure reducer in said return fuel line of said diesel engine, where said pressure reducer is a venturi.

19. The apparatus of claim 18, wherein said venturi is utilized as a fuel flow measurement device.

20. The apparatus of claim 17, further including a pressure reducer in said return fuel line of said diesel engine, where said pressure reducer is a venturi.

1/13

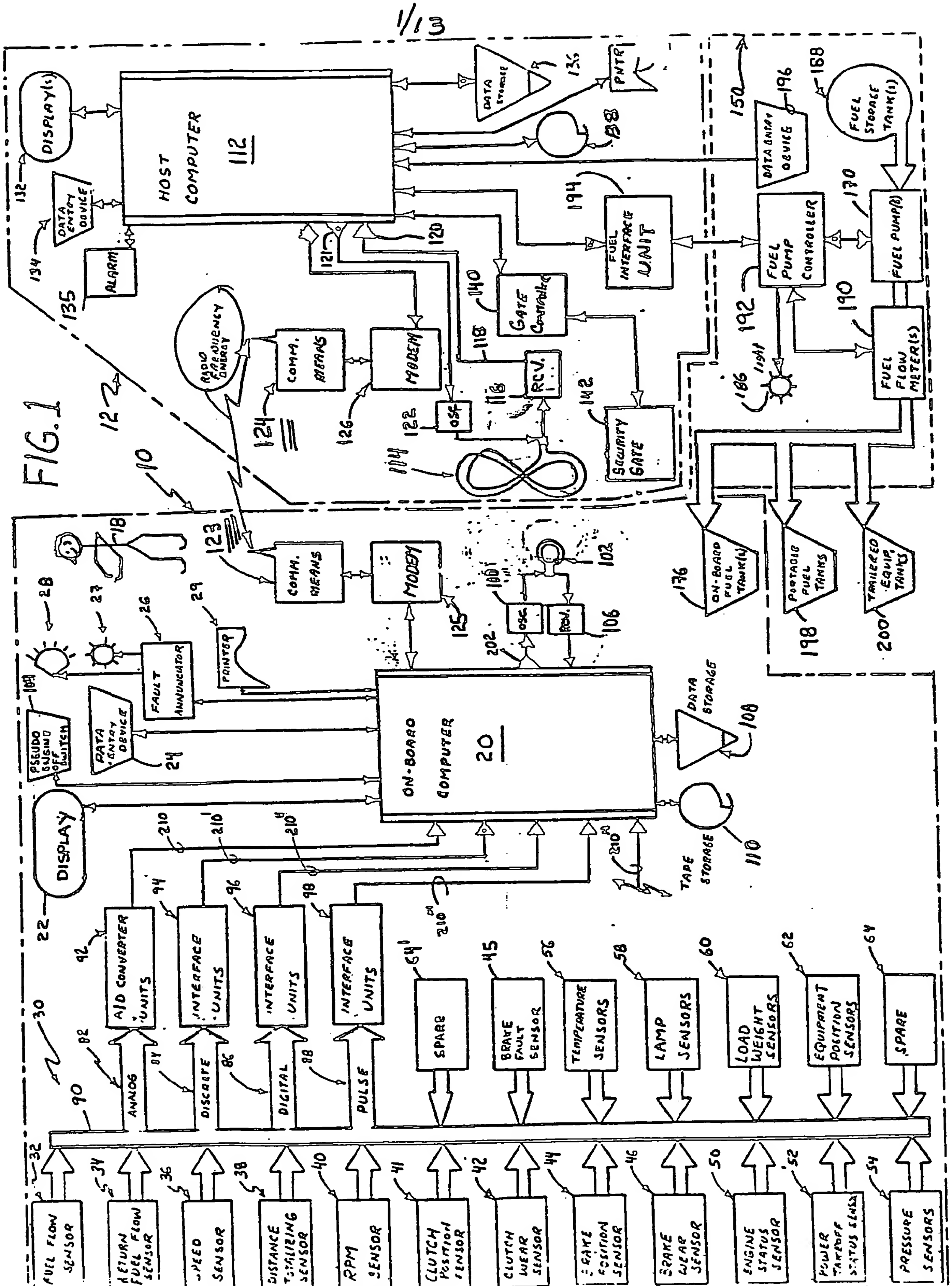

HOST COMPUTER
112
DISPLAY(S)
DATA ENTRY DEVICE
ALARM
DATA STORAGE
PNTR
FUEL INTERFACE UNIT
DATA ENTRY DEVICE
FUEL STORAGE TANK(S)
FUEL PUMP CONTROLLER
FUEL PUMP(S)
FUEL FLOW METER(S)
GATE CONTROLLER
RCV.
MODEM
COMM. MEANS
RADIO FREQUENCY ENERGY
OSC
SECURITY GATE
ON-BOARD FUEL TANK(S)
PORTABLE FUEL TANKS
TRAILERED EQUIP. TANKS
COMM. MEANS
MODEM
OSC.
RCV.
FAULT ANNUNCIATOR
PRINTER
PSEUDO ENGINE OFF SWITCH
DATA ENTRY DEVICE
DISPLAY
ON-BOARD COMPUTER
20
DATA STORAGE
TAPE STORAGE
A/D CONVERTER UNITS
INTERFACE UNITS
INTERFACE UNITS
INTERFACE UNITS
SPARE
BRAKE FAULT SENSOR
TEMPERATURE SENSORS
LAMP SENSORS
LOAD WEIGHT SENSORS
EQUIPMENT POSITION SENSORS
SPARE
ANALOG
DISCRETE
DIGITAL
PULSE
FUEL FLOW SENSOR
RETURN FUEL FLOW SENSOR
SPEED SENSOR
DISTANCE TOTALIZING SENSOR
RPM SENSOR
CLUTCH POSITION SENSOR
CLUTCH WEAR SENSOR
BRAKE POSITION SENSOR
BRAKE WEAR SENSOR
ENGINE STATUS SENSOR
POWER TAKEOFF STATUS SENSOR
PRESSURE SENSORS

FIG. 1

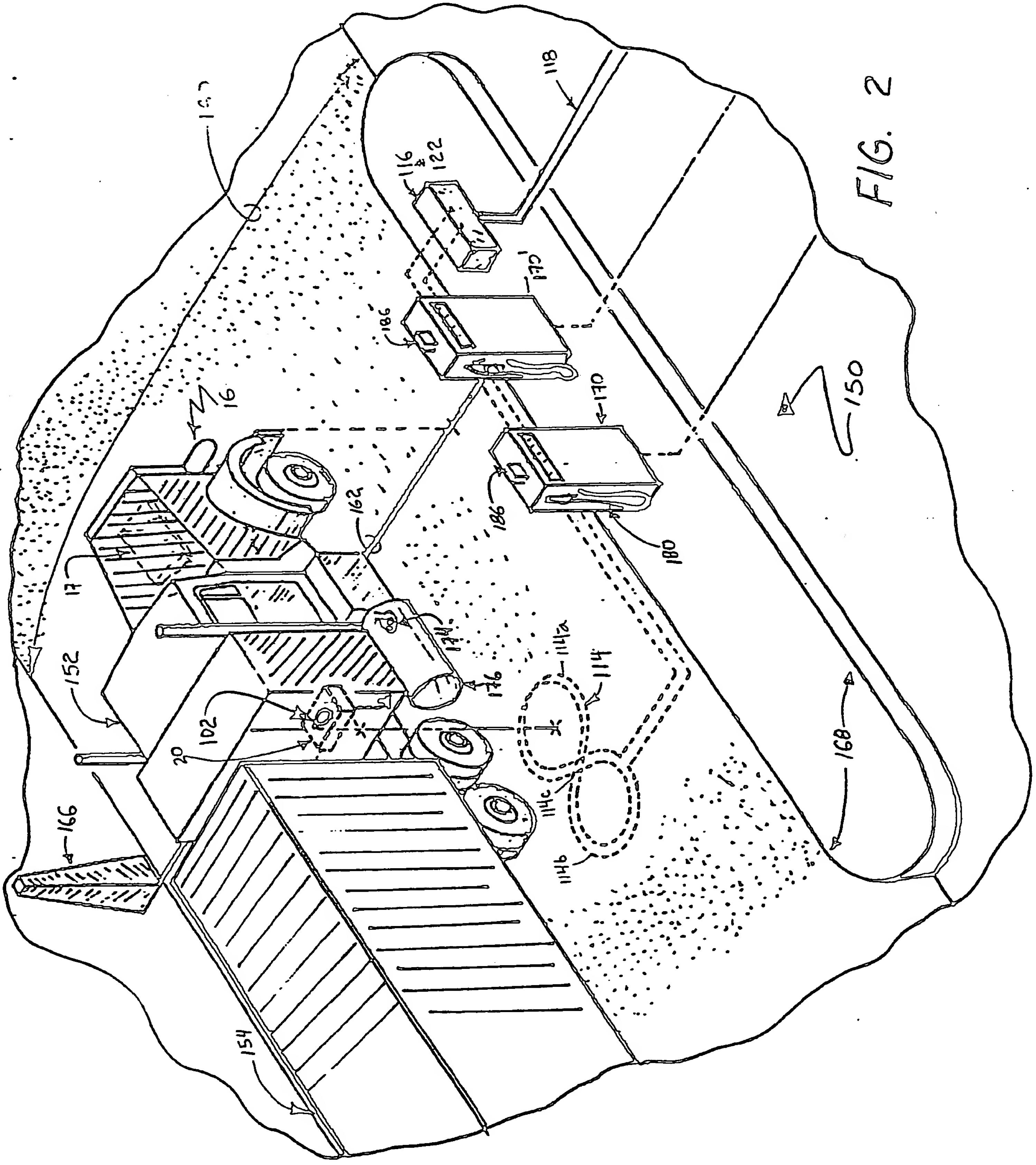

118
116 & 122
172
186
170
186
180
150
16
17
162
174
176
114a
114
114c
114b
102
20
152
166
168
154

FIG. 2

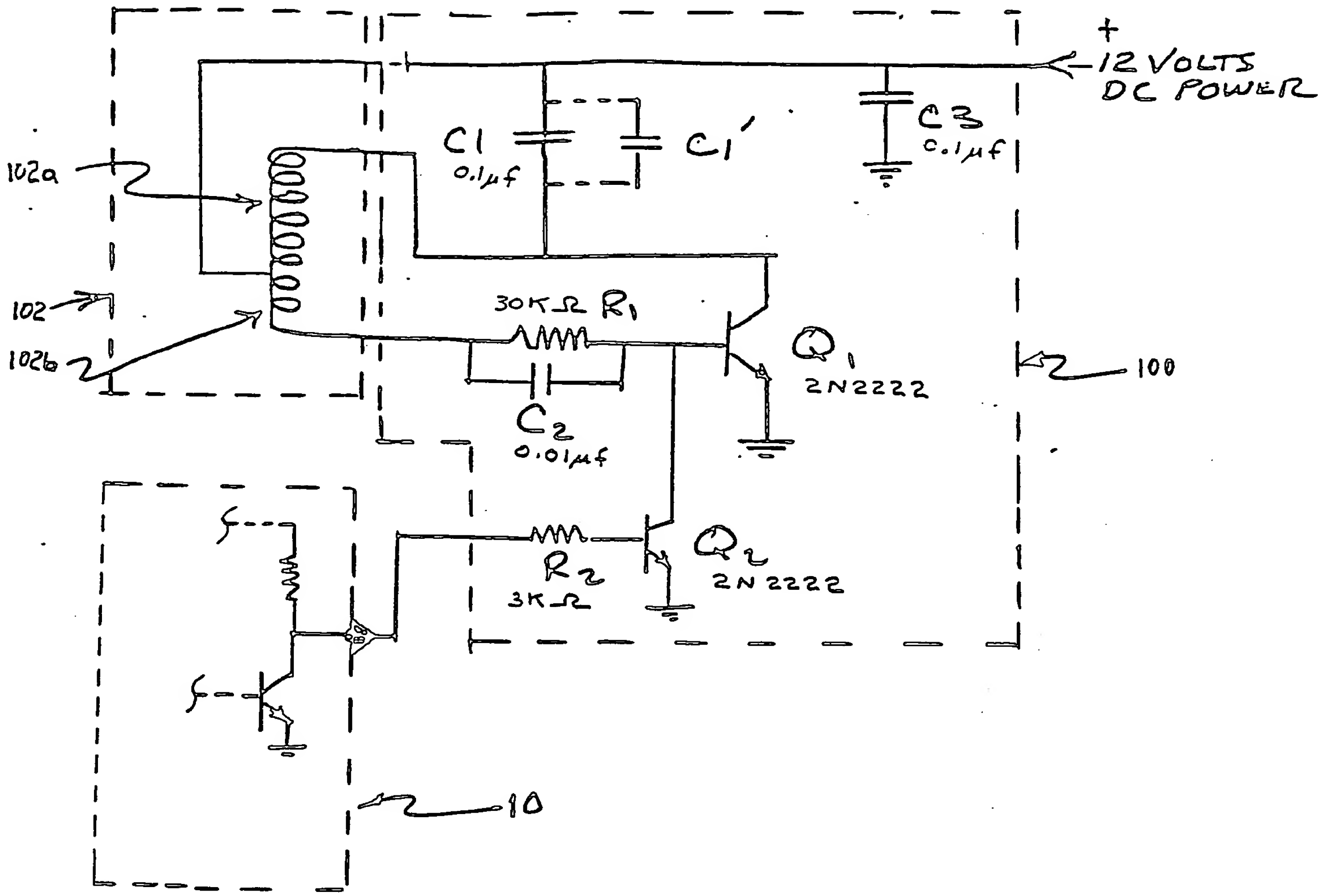

+
12 VOLTS DC POWER
C1
0.1μf
C1'
C3
0.1μf
102a
102
102b
30KΩ R1
Q1
2N2222
100
C2
0.01μf
Q2
2N2222
R2
3KΩ
10

FIG. 3

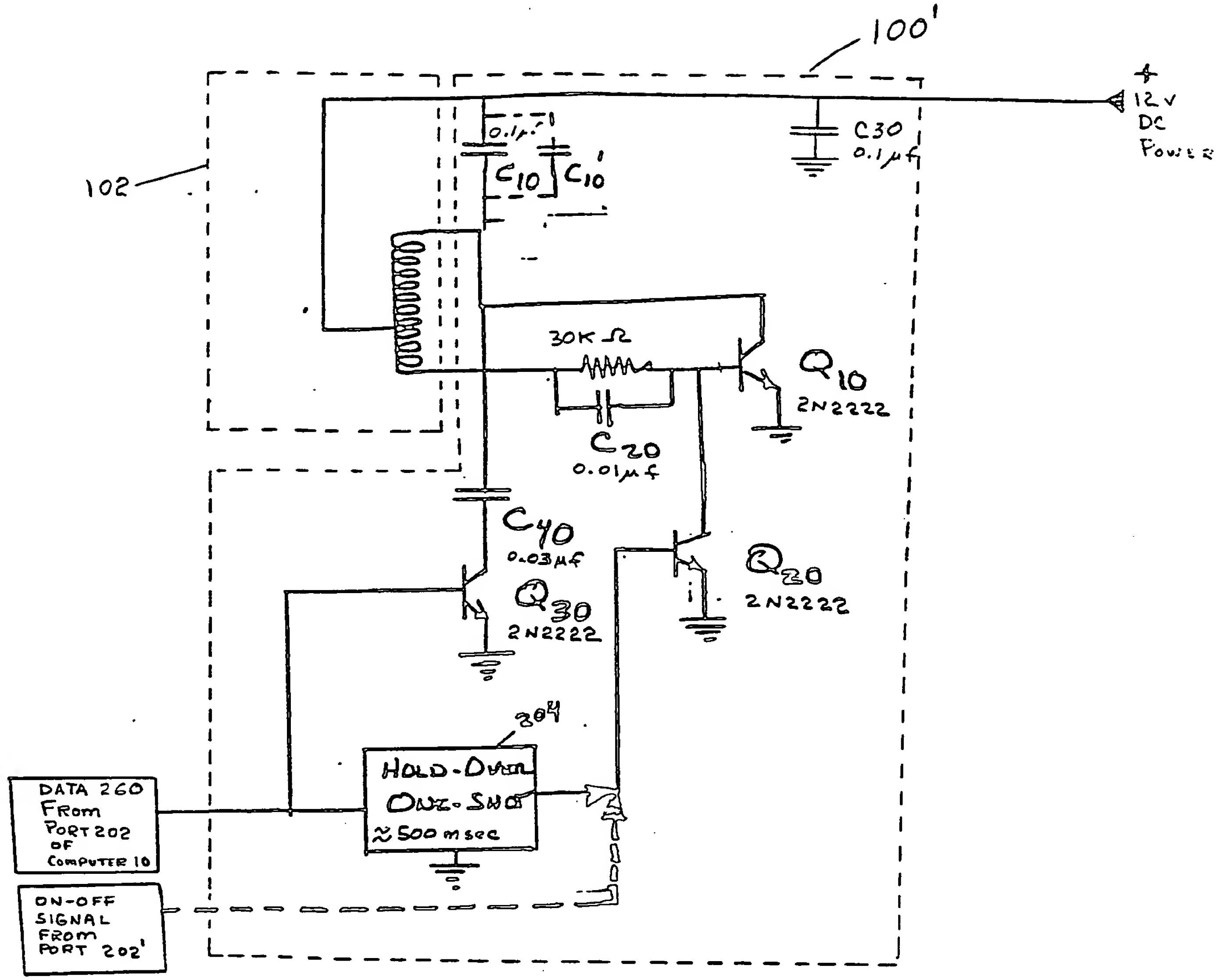

100'
+
12v
DC
Power
C30
0.1μf
0.1μf
C10
C10'
102
30K Ω
Q10
2N2222
C20
0.01μf
C40
0.03μf
Q30
2N2222
Q20
2N2222
304
HOLD-OVER
ONE-SHOT
≈ 500 msec
DATA 260
FROM
PORT 202
OF
COMPUTER 10
ON-OFF
SIGNAL
FROM
PORT 202'

FIG. 4

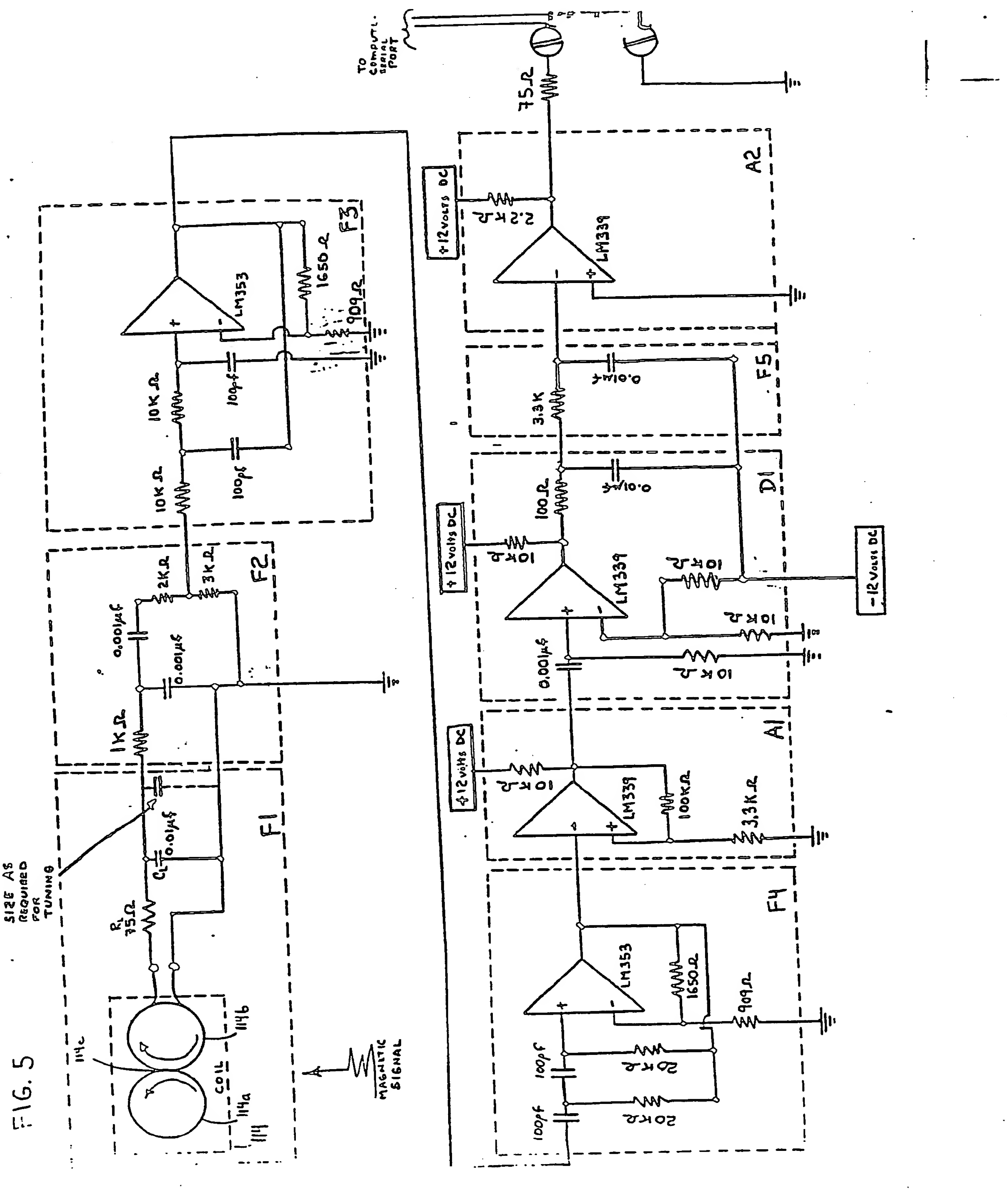

TO COMPUTER SERIAL PORT
75Ω
A2
+12 volts DC
2.2KΩ
LM339
F5
0.01μf
3.3K
D1
100Ω
10KΩ
-12 volts DC
0.001μf
A1
100KΩ
3.3KΩ
F4
LM353
1650Ω
909Ω
20KΩ
100pf
F3
10KΩ
F2
2KΩ
3KΩ
1KΩ
F1
0.01μf
$C_L$
$R_L$ 75Ω
SIZE AS REQUIRED FOR TUNING
COIL
114a
114b
114c
111
MAGNETIC SIGNAL

FIG. 5

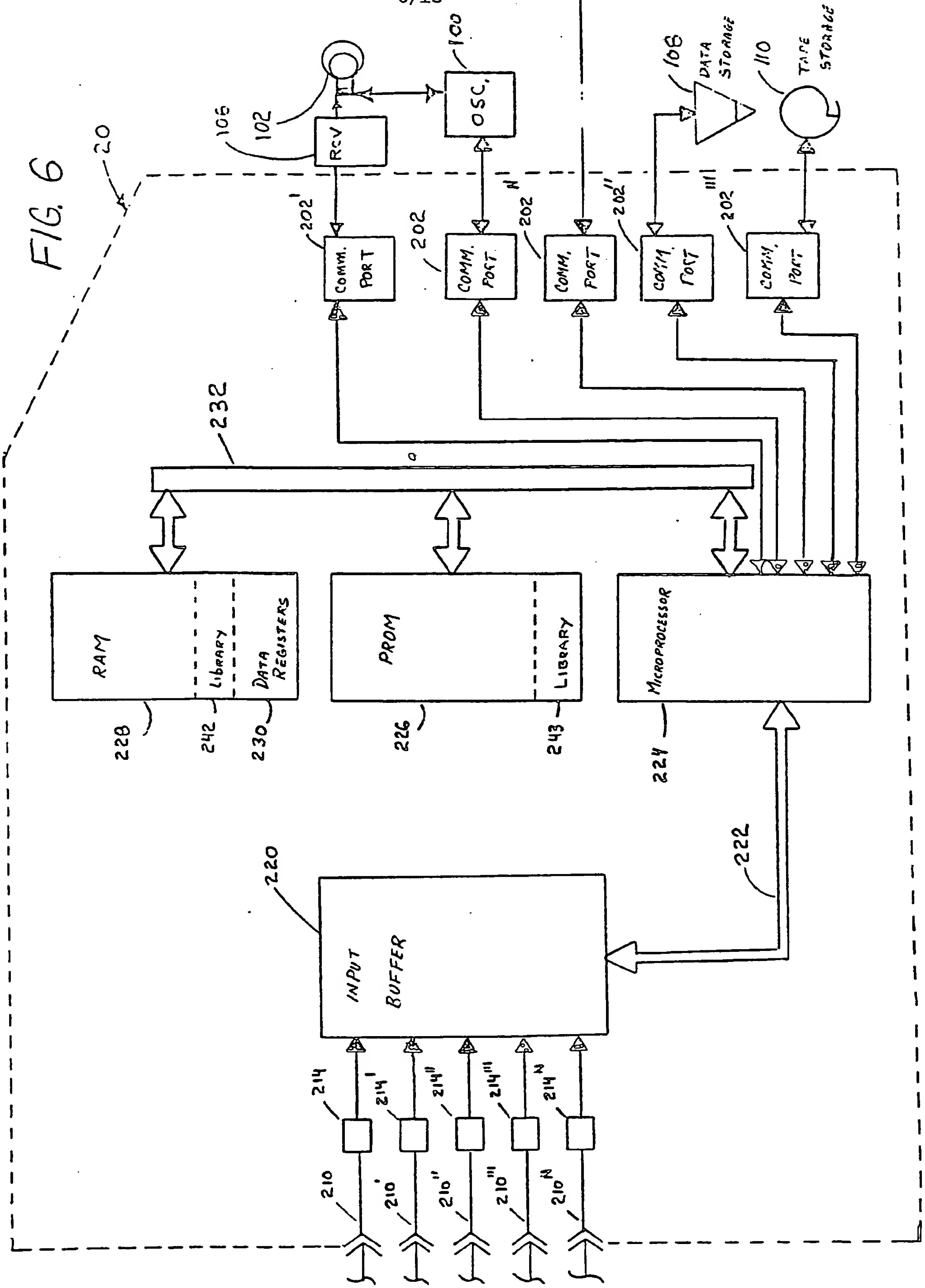

20
RCV
OSC.
DATA STORAGE
TAPE STORAGE
COMM. PORT
INPUT BUFFER
RAM
LIBRARY
DATA REGISTERS
PROM
LIBRARY
MICROPROCESSOR
100
102
106
108
110
202
232
228
242
230
226
243
224
222
220
214
210

FIG. 6

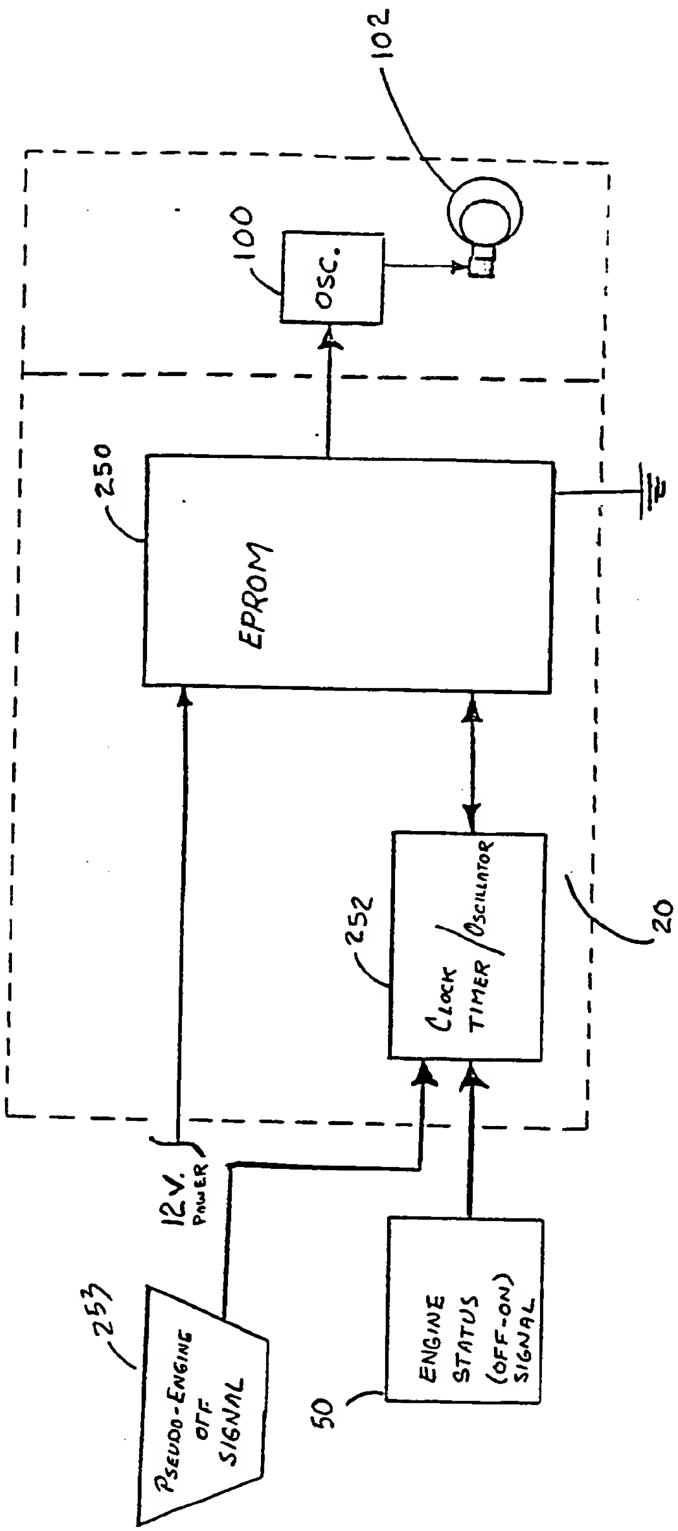
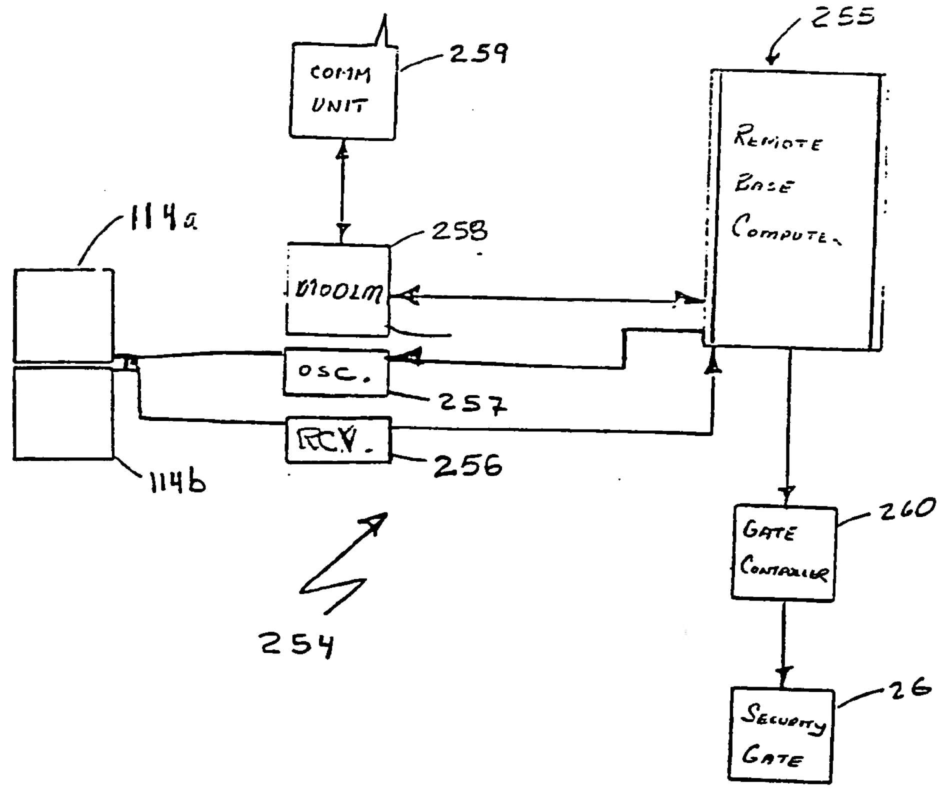

102
100
OSC.
250
EPROM
252
CLOCK TIMER/OSCILLATOR
20
12V. POWER
253
PSEUDO-ENGINE OFF SIGNAL
50
ENGINE STATUS (OFF-ON) SIGNAL

FIG. 7



COMM UNIT
259
255
REMOTE BASE COMPUTER
114a
258
MODEM
OSC.
257
RCV.
256
114b
254
GATE CONTROLLER
260
SECURITY GATE
261


FIG. 8

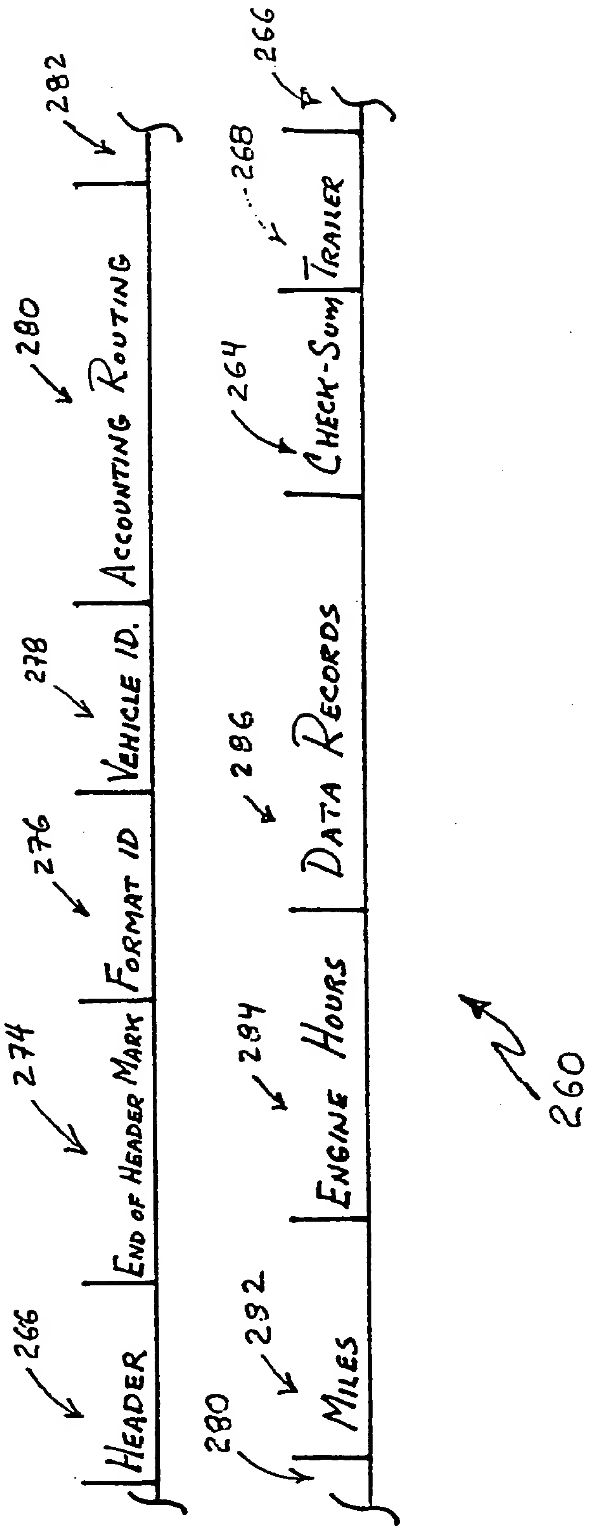

HEADER
END OF HEADER MARK
FORMAT ID
VEHICLE ID.
ACCOUNTING ROUTING
MILES
ENGINE HOURS
DATA RECORDS
CHECK-SUM
TRAILER
266
274
276
278
280
282
292
294
296
264
268
266
280
260

FIG. 9

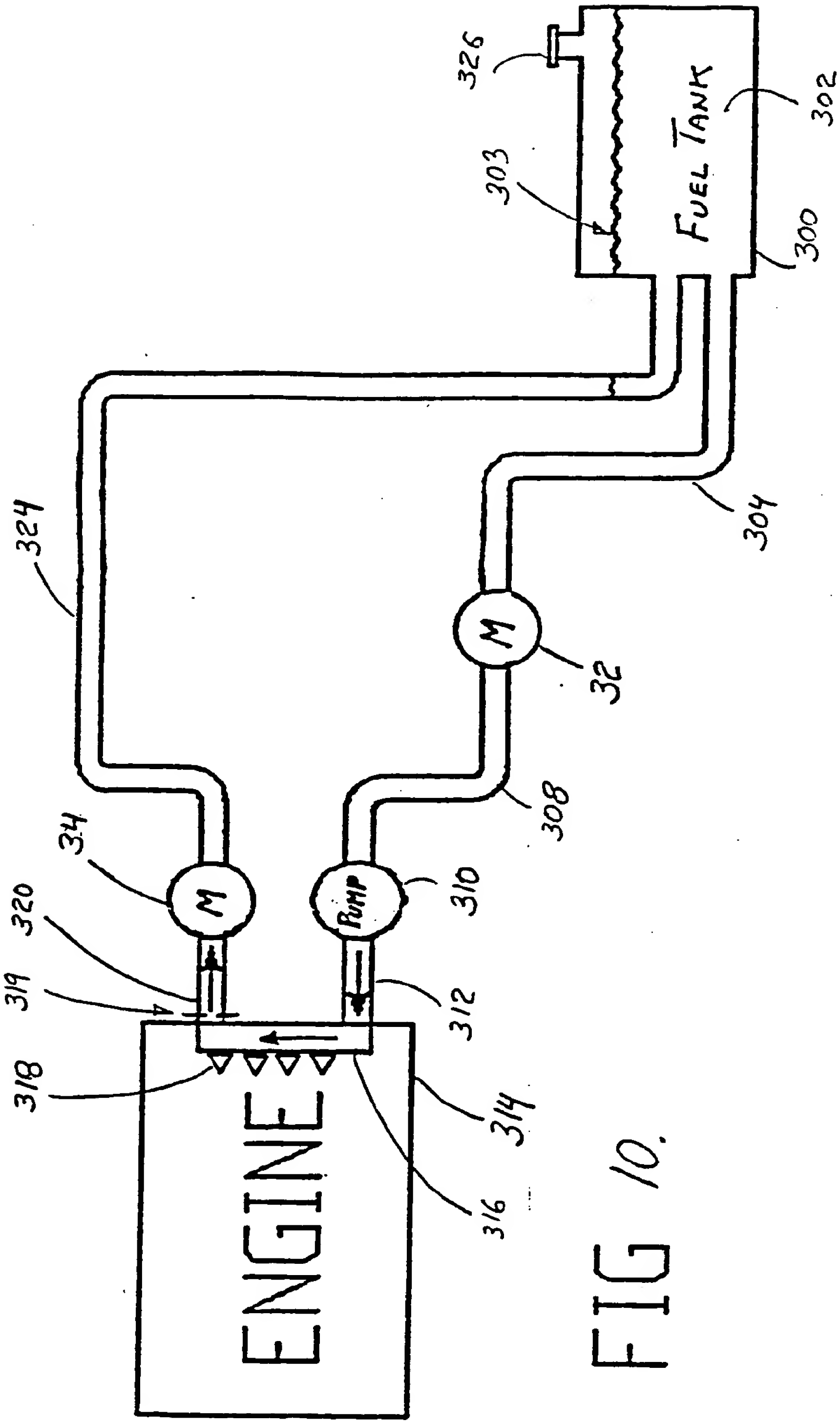

FUEL TANK
ENGINE
PUMP
M
M
326
302
303
300
304
324
32
308
34
310
320
319
312
318
314
316

FIG 10.

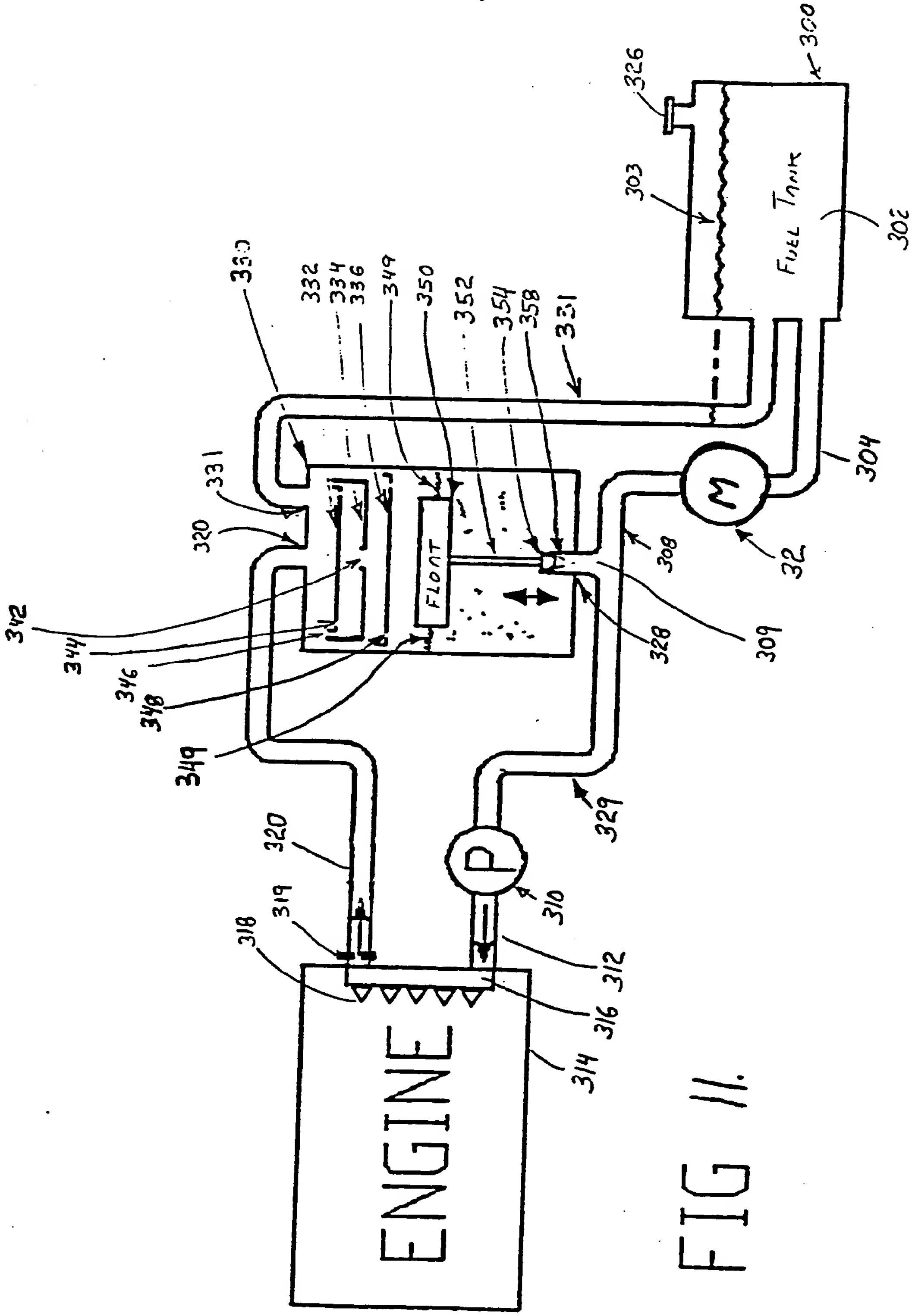

ENGINE
FLOAT
FUEL TANK
M
P
300
302
303
304
308
309
310
312
314
316
318
319
320
326
328
329
331
332
334
336
342
344
346
348
349
350
352
354
358
32

FIG 11.

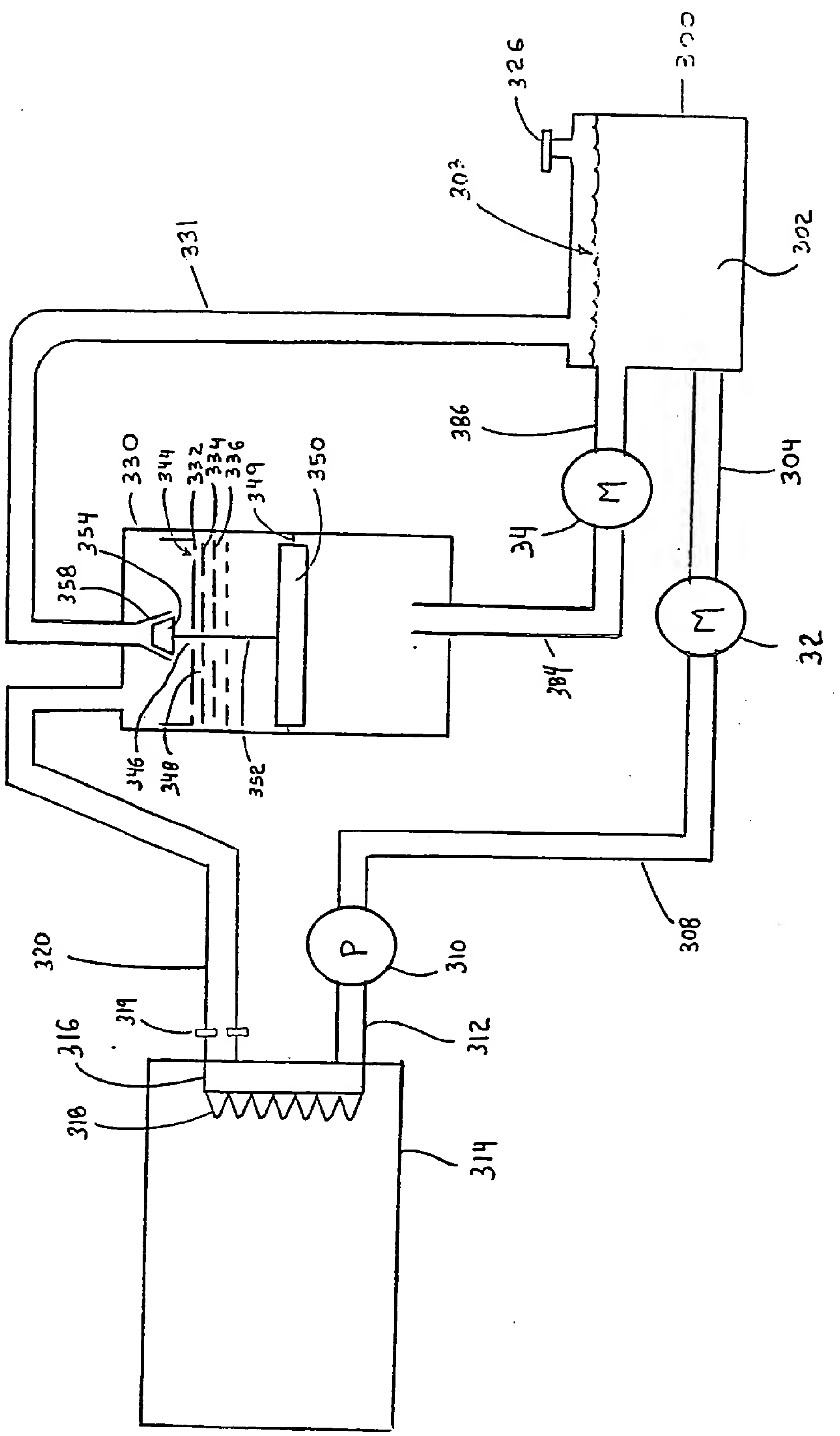

300
326
303
302
331
386
304
M
34
M
32
330
344
332
334
336
349
350
354
358
384
346
348
352
308
P
310
320
319
316
318
312
314

FIG. 12

FIG. 13

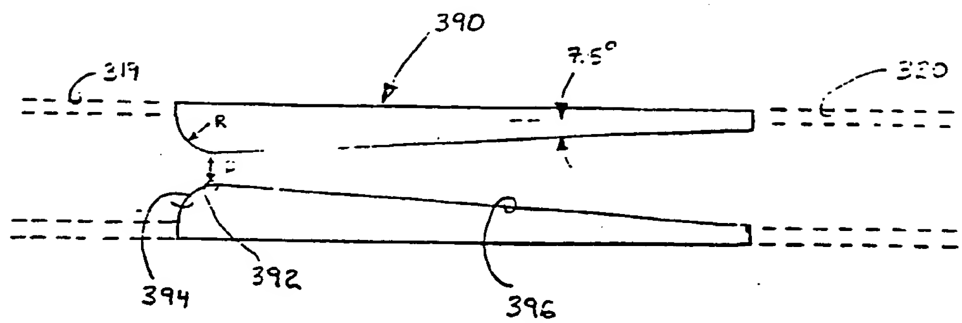
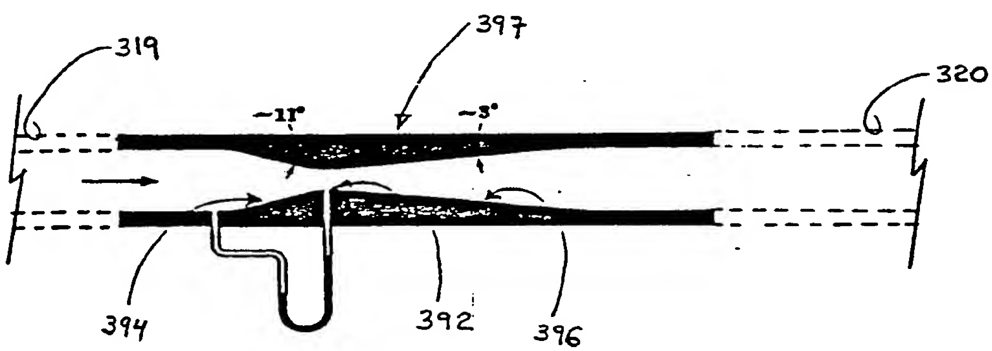



FIG. 14



# INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/01736

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC.(5): G06F 13/00; H04B 5/00

U.S. CL.: 364/551.01, 424.04; 340/933, 825.54; 235/382

**II. FIELDS SEARCHED**

Minimum Documentation Searched [4]

| Classification System | Classification Symbols |
|---|---|
| U.S. | 364/141,184,185,550,551.01,424.01,424.03,464..01, 465.401; 340/933, 438,439,457.4,459; 235/378,382.5,384; 73/114,119A |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [6]

APS:(Coil# or Loop#) (4A) Magetic? (P) (Transmi#### or Communicat#####) and (on Board or Remote) (P) (Processor# or Computer#) and (Vehicle# or Engine#) (P) Monitor?

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [14]

| Category ° | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No. [18] |
|---|---|---|
| Y,E | US, A, 4,926,494 (POTTER) 15 May 1990 See Fig.2. | 1-9,14 and 16 |
| Y,E, | US, A, 4,926,331 (WINDLE ET AL.) 15 May 1990 See entire document. | 1-9,14 and 16 |
| Y,P | US, A, 4,897,642 (DILULLO ET AL.) 30 January 1990 See entire document. | 1-9,14 and 16 |
| Y,P | US, A, 4,853,859 (MORITA ET AL.) 01 August 1989 See entire document. | 1-9,14 and 16 |
| Y | US, A, 4,808,803 (MORITA ET AL.) 01 August 1989 See entire document. | 5 |
| Y | US, A, 4,804,937 (BARBIAUX ET AL.) 14 February 1989 See abstract and Fig. 1,2. | 1-9,14 and 16 |
| Y | U , A, 4,714,925 (BARTLETT) 22 December 1987 See abstract and Fig 1. | 1-9,14 and 16 |

° Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search [2] | Date of Mailing of this International Search Report [2] |
|---|---|
| 21 JUNE 1990 | 26 JUL 1990 |
| **International Searching Authority** [1] | **Signature of Authorized Officer** [20] |
| ISA/US | JOSEPH L. DIXON |

**FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET**

| | | |
|---|---|---|
| Y | Phillips Telecommunications Review, Vol. 41, No.3, September 1983, N. Van Tol, "Vecom Short-range communication with vehicles" p. 235-249. | 1-9,14 and 16 |
| Y | US, A, 4,344,136 (PANIK) 10 August 1982 See Fig.1B and abstract. | 1-9,14 and 16 |
| A | US, A, 4,630,292 (JURICICH ET AL.) 16 December 1986, See entire document. | 10 |
| A | US, A, 4,490,798 (FRANKS ET AL.) 25 December 1984, See entire document. | 5,6, and 9 |

**V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]**

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter [1] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ........, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [1], specifically:

3. ☐ Claim numbers________, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

**VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]**

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/US90/01736

| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) | | |
|---|---|---|
| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No [18] |
| A | US, A, 4,450,820 (HAYNES) 29 May 1984, See entire document. | 15 and 17-20 |
| A | US, A, 3,817,273 (ERWIN, JR.) 18 June 1974, See entire document. | 15 and 17-20 |
| A | US, A, 3,672,394 (ERWIN, JR.) 27 June 1972, See entire document. | 15 and 17-20 |
| Y | US, A, 4,263,945 (VAN NESS) 28 April 1981, See Fig.1, 4 and abstract. | 5,6 and 9 |
| Y | US, A, 4,258,421 (JUHASZ ET AL.) 24 March 1981, See entire document. | 1-9,14 and 16 |
| Y | US, A, 4,067,061 (JUHASZ ) 03 January 1978, See entire document. | 1-9,14 and 16 |
| Y | WIRELESS WORLD, Vol, 81, No. 1474, June 1975 "Aid For Drivers", p. 269-70. | 1-9,14 and 16 |